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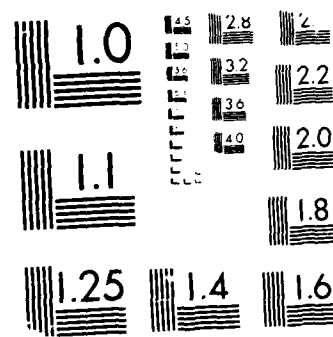
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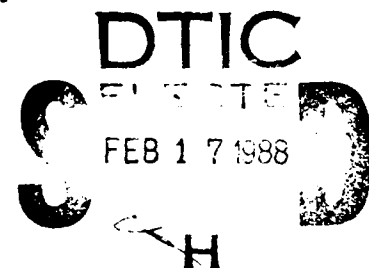
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January 1988  
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## WATERFRONT DAMAGE REPAIR FOR AMPHIBIOUS AND ADVANCED BASES

**ABSTRACT** This study examines present damage assessment and repair techniques for advanced base waterfront facilities. Limited planning has been done to identify mission objectives and operation requirements for these facilities.



NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043

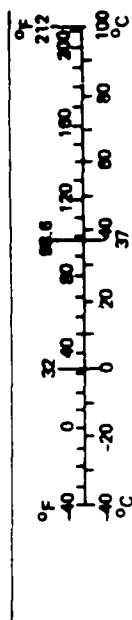
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# METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures				Approximate Conversions from Metric Measures			
Symbol	When You Know	Multiply by	To Find	Symbol	When You Know	Multiply by	To Find
<b>LENGTH</b>				<b>LENGTH</b>			
in	inches	2.5	centimeters	mm	millimeters	0.04	inches
ft	feet	30	centimeters	cm	centimeters	0.4	inches
yd	yards	0.9	meters	m	meters	3.3	feet
mi	miles	1.6	kilometers	km	kilometers	1.1	yards
<b>AREA</b>				<b>AREA</b>			
in <sup>2</sup>	square inches	6.5	square centimeters	cm <sup>2</sup>	square centimeters	0.16	square inches
ft <sup>2</sup>	square feet	0.09	square meters	m <sup>2</sup>	square meters	1.2	square yards
yd <sup>2</sup>	square yards	0.8	square meters	km <sup>2</sup>	square kilometers	0.4	square miles
mi <sup>2</sup>	square miles	2.6	square kilometers	ha	hectares (10,000 m <sup>2</sup> )	2.5	acres
<b>MASS (weight)</b>				<b>MASS (weight)</b>			
oz	ounces	28	grams	g	grams	0.035	ounces
lb	pounds	0.45	kilograms	kg	kilograms	2.2	pounds
	short tons (2,000 lb)	0.9	tonnes	t	tonnes (1,000 kg)	1.1	short tons
<b>VOLUME</b>				<b>VOLUME</b>			
ts	teaspoons	5	milliliters	ml	milliliters	0.03	fluid ounces
Tbsp	tablespoons	15	milliliters	l	liters	2.1	pints
fl oz	fluid ounces	30	milliliters	l	liters	1.06	quarts
c	cups	0.24	liters	l	liters	0.26	gallons
p	pints	0.47	liters	m <sup>3</sup>	cubic meters	36	cubic feet
qt	quarts	0.95	liters	m <sup>3</sup>	cubic meters	1.3	cubic yards
gal	gallons	3.8	liters	°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature
ft <sup>3</sup>	cubic feet	0.03	cubic meters				
yd <sup>3</sup>	cubic yards	0.76	cubic meters				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature				

\*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Meas. Publ. 286, Units of Weights and Measures, Price \$2.25, SD Catalog No. C13.10.286.



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## SECTION 1

### INTRODUCTION

#### 1.1 BACKGROUND

The purpose of this report is to provide general guidance for assessing damaged waterfront facilities and to recommend methods of expedient repair. This will allow the shipment of supplies for military troops in a Theater of Operations (TO) to continually function. The information that was developed is an answer to military and non-military damage inflicted upon the waterfront facility.

This is in response to the identification of war damage, by the Naval Maritime Strategy, as a critical Naval Construction Force (NCF) capability. Limited planning has been done to identify mission objectives and operation requirements for advanced base waterfront facilities. Expedient damage assessment and repair techniques are to be addressed.

#### 1.2 SCOPE

The scope of this investigation includes a review of available publications to identify methods and materials used in previous damaged facilities. Specific purposes were to provide identification of mission objectives and operational requirements, including required restoration times; identification of repair replacement concepts, including those requiring further development.

### 1.3 SUMMARY

Expedient damage assessment and repair of waterfront facilities has had limited planning to identify mission objectives and operation requirements. This study examines present damage assessment and repair techniques and elaborates on new systems which can be incorporated into the damage repair scheme.

The areas which are examined are types of damage that can occur to the waterfront facility, damage assessment, and repair method. Special attention is given to new methods concerning each area of discussion.

### 1.4 CONCLUSIONS

The following conclusions are drawn from this study:

- o The requirements for waterfront damage repair are inherent in the Strategic Sealift Mobility programming of ships necessary to sustain deployed forces but they are not specifically stated.
- o Procedure guidelines need to be developed for waterfront damage assessment operations.
- o Utilities and cargo transfer systems are presently not covered under waterfront damage assessment operations.
- o The use of artificial intelligence is not incorporated into the present damage assessment scheme.
- o The construction force which is delegated to the repair

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- o Procedure guidelines need to be developed for waterfront damage assessment operations.
- o Utilities and cargo transfer systems are presently not covered under waterfront damage assessment operations.
- o The use of artificial intelligence is not incorporated into the present damage assessment scheme.
- o The construction force which is delegated to the repair

operation does not stockpile or have pre-constructed modular repair packages.

- o Repair concepts from other areas of design need to be integrated into present repair methods.
- o Existing removal/repair equipment needs to be upgraded to involve available new commercial systems for use in waterfront damage repair.
- o Engineers must work with second hand information in the area of underwater assessment, therefore clear, color pictorials are very important.
- o The requirements for waterfront damage repair are inherent in the Strategic Sealift Mobility programming of ships necessary to sustain deployed forces but they are not specifically stated.
- o It is impractical to procure, ship, and stock pile damage repair material and equipment at each advance base. The indigenous resources should be investigated and identified so as repair methods can be formulated using the available material and equipment.
- o Training the NCF how to do waterfront damage repair requires an approach that will appeal to the educational level of the expected military personnel available. Since most of personnel have been exposed to video games, an educational tool can be devised that would combine the visual display with the challenge of completing the repair with material and equipment at hand within the shortest time possible or before something else happens (e.g ship ready to dock, supplies needed at the front, troops are in danger of

attack, etc.). This type of training could be augmented with some realistic training aids similar to "butter-cup" damage control training done by the NAVY.

- o Military exercises testing the capabilities of advance base survivability, such as Salty Demo, have been documented by a 16 Volume report. To achieve the most benefit from these exercises, a detailed review is necessary to extract the "lessons learned" as they relate to waterfront repair and formulate a viable program of investigations, corrections and testing to validate effectiveness of solutions prior to fleet introduction.
- o The use of knowledge based expert systems have not been incorporated into the damage assessment and repair methodology for damaged waterfront facilities.

#### 1.5 RECOMMENDATIONS

The following recommendations are made as a result of this study:

- o The inherent requirements of continuous Advance Base Operations to insure the timely restoration of cargo throughput after enemy action need to be specifically stated and actively supported.
- o Assessment guidelines should be developed in a manner such to parallel naval bridge inspection and offshore structure inspection.
- o Utilities and cargo transfer systems need methods to evaluate damage assessment and provide for expedient repair.

- o Artificial intelligence should be incorporated into underwater assessment. The use of ROV's (e.g. miniROVER) and towed bodies (e.g. side scan sonar) should be used in combination with diving inspection teams. These inspection systems can be used to gather information from small cramped areas or over wide areas in detail.
- o Repair methods presently used in other areas of structural design, should be used in waterfront damage repair. The methods include king post truss method, isolation bearings and steel plate foundation.
- o The use of assessment instrumentation should be incorporated into the structure during construction. Such as strain gauges, which can be used at anytime to analyze the load carrying capacity of the structure.
- o The construction force should stockpile pre-constructed modular repair packages to be used in several damage repair scenarios.
- o Available commercial repair/removal equipment (e.g., waterjet cutters) should be used to upgrade damage/removal equipment (e.g., diamond saws) presently being used.
- o Some engineers should be qualified divers to assist the inspection of the underwater structure and to develop an assessment of the critical components.
- o The inherent requirements of continuous Advance Base Operations to insure the timely restoration of cargo throughput after enemy action need to be specifically stated and actively supported.

- o Advanced Planning of how to do waterfront damage repair with indigenous resources needs to be investigated and repair methods will be formulated using the available material and equipment.
- o Training aids that would combine real time interaction between the student and the visual display similar to a "video game" is needed. The challenge of completing the repair with material and equipment at hand within the shortest time possible or before something else happens; e.g. ship ready to dock, supplies needed at the front, troops are in danger of attack, etc., should be included. This training should be augmented with some realistic full size training aids similar to "butter-cup" damage control training done by the NAVY.
- o Review and extract the "lessons learned" as they relate to task of the waterfront damage repair and formulate corrections with testing necessary to validate effectiveness of solutions.
- o The use of a knowledge based expert system should be analyzed to be used as a planning/training tool for waterfront damage repair.

## SECTION 2

### DISCUSSION

#### 2.1 WATERFRONT DAMAGE REQUIREMENTS

As expressed by Admiral Trost in his January 1987 Proceedings article; "Our National Defense Strategy rests on three pillars: deterrence, forward defense, and allied solidarity." The forward defense pillar is highly dependent of having advance basing to support the deployed forces. The Naval Construction Force (NCF) will establish and man the forward logistic support base to insure sustainability of the operational forces. These forward base facilities are the "Force Multipliers" as stated by LCDR McAfee in his July 1987 Military Engineer article on "Facilities Readiness, A Strategic Imperative". To insure these advanced bases are available when needed, a waterfront survivability program is needed.

The Naval Maritime Strategy identifies war damage repair as a critical NCF capability. Limited planning has been done to identify mission objectives and operation requirements for advance base waterfront facilities.

Waterfront damage repair is a generic operation conducted by the NCF in time of conflict along with the facilities current operator/owner. Little has been done to upgrade the NCF capability to keep in step with the advance weapons that will be used early on in any conflict to disrupt the cargo throughput. Advanced bases that shorten the logistics supply lines in the past were beyond the range of conventional weapons. Today's smart, long range weapons will present new challenges to

repairing damaged port facilities. Damage assessment methods and equipment must be on hand to provide data quickly, with sufficient and accurate detail to layout repair plans that will restore the flow of cargo. These facilities include harbor anchorages, channels, locks, bridges, piers, jetties, material handling equipment, utilities, storage areas, harbor utility craft, ship repair facilities, communication/navigation controls, and internal transportation system.

The Joint Army/Navy Strategic Mobility Program Development and Coordination, Memorandum of Agreement signed in December 1986, includes tasks to identify a family of deployable waterfront facilities to serve as portable ship unloading for mobile logistics support. This would be the extreme ultimate answer to waterfront damage repair.

NATO has produced a guide outlining the Restoration of Facilities of Communications, Ports, and Other Critical Installations After Hostile Action. This report examines key areas and identifies the local responsible organizations who will organize and prioritize the restoration operations in conjunction with the area needs. There are no Navy specific manuals to aid in base recovery, no equipment or repair items determined or specified.

The idea of our fixed advanced bases sustaining operations in conflict is very often voiced in our Maritime Strategy, but the details of base mission restoration have not been articulated and assigned a priority to assure timely completion. The time phased throughput, ship turn around times, and the restoration of other resources necessary to sustain the mission need to be quantified. Predictions of potential damage are required to assist in planning to assure the requisite repair material and equipment is on hand. Then the Operational Requirements for war damage repair of port facilities needs to be expressed in the

proper programmatic format necessary for staffing and program status.

Figure 2-1 illustrates a work breakdown structure which reflects the required functions and repair requirements for a damaged waterfront.

# WATERFRONT DAMAGE REPAIR FOR ADVANCED AND AMPHIBIOUS BASES

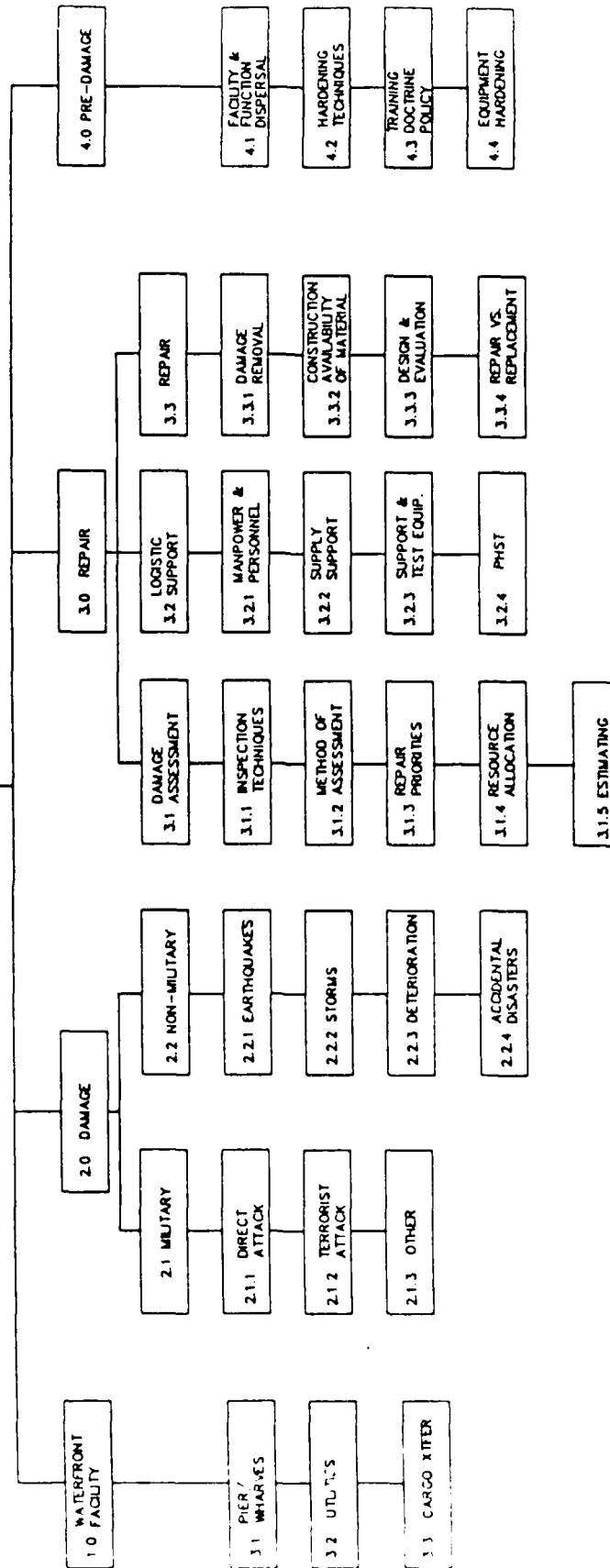


Figure 2-1.  
A Work Breakdown Structure for Waterfront Damage Repair.

## **2.2 DAMAGE**

This section details possible damage on the operating waterfront facility. Types of damage expected are broken into two main headings, military and non-military. Each will be addressed separately.

### **2.2.1 MILITARY DAMAGE**

The purpose of this section is to examine possible military threats. Damage can be assumed to be minimal damage (small damage to piles, decking, cargo equipment) to total destruction dependent upon weapons destructive force (e.g., damage scenarios use damage inflicted by 250 kg. general purpose bombs which explode on impact and leave craters which average 8.4 feet in diameter).

The use of computer generated damage simulations, such as the Monte Carlo bomb damage computer programs, should be utilized to assist in advanced planning. This type of simulation will demonstrate damage scenarios which are proportional to possible attack scenarios experienced. To further aid in the construction of military missions, the review of previous military exercises, such as Salty Demo, would further assist in advanced planning for advanced military bases.

#### **2.2.1.1 Paramilitary/Clandestine Attack**

These insurgent attacks will likely be directed against such targets as stored cargo, moored vessels and the facility structure. There are an extensive array and variety of exotic, as well as conventional weapons, that can be used by insurgent forces. Many Third World Nations are being supplied with weapons by the Soviets and others. Suicide missions are common and cannot be discounted when considering this threat. Some standard

weapons used extensively in destroy and disrupt missions by clandestine forces are mortars, rocket-type weapons such as the bazooka, and explosive/demolition charges.<sup>6</sup>

#### **2.2.1.2 Direct Attack**

The following discussion is broken into three subheadings: air-launched, surface launched and land launched attacks. The information is taken from Department of the Navy Report - Airbase Survivability (ABS) Master Plan.<sup>6</sup>

##### **2.2.1.2.1 Air-launched Attacks**

All of the major powers and many of the Third World nations have an air force. As international crises develop in which the U.S. is taking an active role, it is feasible that an airstrike can be launched against one or more of our forward airbases. Attacks can be made from low, medium, or high altitude, and from short, medium, or long range. Targets for air attack are the same as for clandestine attacks, but targeting for air attack will require different intelligence. Targets will be based on target discrimination. If a target is difficult to locate or distinguish from the air, it is very difficult to hit. Many guided weapon sensors require certain forms of target data in order to be effective. The destructiveness of current and projected air-launched weapons combined with the speed of modern aircraft make this form of attack highly probable. Suicide air strikes are certainly a possibility and must be considered as a part of the threat. Weapons that can be used range from conventional bombs, rockets, and guns to the more exotic specialized guided weapons that can take out specific facilities with pinpoint accuracy.

The damage that occurs, will vary in degree depending upon the strength of the opposing force. The types of damage that

would be seen are: cratering of the deck, pile fracture and failure, overloading of structural members, and foundation deterioration.

#### 2.2.1.2.2 Surface-launched Attacks

Although surface-launched naval attacks are a lower probability, there is still a potential threat from this type of attack. Cruise missiles can be launched from relatively small and speedy craft as well as from gunboats, frigates, destroyers, cruisers, or battle cruisers. In addition to the cruise missiles, there are conventional gun systems with special projectile provisions such as armor piercing, penetration, and persistent agents that can be used against targets.

The damage that occurs, will vary in degree depending upon the strength of the opposing force. The types of damage that would be seen are: cratering of the deck, pile fracture and failure, overloading of structural members, and foundation deterioration.

#### 2.2.1.2.3 Land Based Attacks

U.S. Forces experienced a primitive form of land based attack during the conflict in Vietnam. The bases were attacked with unguided rockets launched from very simple launchers. Although they were more harassment than destructive, they did do some significant damage. Even in this relatively unsophisticated environment, U.S. forces were required to revise their normal operating routines, and to take special actions to provide for improved protective sheltering for personnel, craft, and facilities. Weapons that are available today are much more accurate and destructive.

The damage that occurs, will vary in degree depending upon

the strength of the opposing force. The types of damage that would be seen are: cratering of the deck, pile fracture and failure, overloading of structural members, and foundation deterioration.

#### **2.3.1 NON-MILITARY DAMAGE**

This category incorporates damage that is brought about by non-military methods. This includes natural occurring incidents such as earthquakes, hurricanes, natural deterioration as well as other damage such as incidents brought about by human error. The physical properties of each will be analyzed and the effect it implements upon the structure.

##### **2.3.1.1 Earthquakes**

Any of the many effects of an earthquake, such as direct seismic vibration, ground lurching, subaerial and submarine landslides, fires, sea waves, or land level changes can cause extensive damage to waterfront facilities.<sup>1</sup> Following a seismic occurrence the generation of a tsunami is very strong. This also can cause severe damage and/or resulting fire to storage facilities. Induced geological movement may cause the structure to be unreliable for operation. Cranes may be damaged resulting in a reduced loading/unloading capacity. An example of the destructive force is shown by the results of the Alaskan earthquake of 1964 which had a magnitude of 8.35 on the Richter Scale. Many waterfront facilities were rendered practically inoperative, such as Seward and Whittier, or destroyed.

##### **2.3.1.2 Storms**

Storms that can generate winds of 64 knots and above are known as hurricanes in the Atlantic, typhoons in the Pacific, and monsoons in the Indian Ocean. These have caused more damage in

the United States over the years than any other type of natural disaster. Winds, heavy rains, and high tides which comprise the storm can cause major damage and loss of life. In 1900, for example, hurricane winds of some 60 m/sec (120 knots) struck the gulf area in the vicinity of Galveston, Texas, raising the normal expected tidal range of 60 cm (1.96 ft) by an additional 4.6 m (15.1 ft) or more; on top of that were 7 m (23 ft) wind waves by the storm of which considerable damage resulted.<sup>2</sup>

This type of generated force can cause severe damage to an operational waterfront facility. Possible inflicted damage could be as follows: moorings may be torn causing vessels to move freely against other vessels and fixed facilities. Cargo handling facilities and equipment as well as utilities may be damaged or destroyed. Hyper-transport of sediment may be caused by the storm thereby leaving the facility accessible only by ship. Careful planning and advance notice reduce storm related damage.

#### **2.3.1.3 Natural Deterioration Of Structure**

Damage in its various forms affects structural capacity by (1) reducing or altering the net section geometry, (2) reducing the material strength and (3) excessively deforming the member so that the applied load pattern is changed.

##### **2.3.1.3.1 Deterioration Of Steel Structure**

There are six major types and causes of steel structure deterioration in the marine environment: (1) corrosion, (2) abrasion, (3) loosening of structural connections, (4) fatigue, (5) overloading, and (6) loss of foundation material.<sup>3</sup>

#### 2.3.1.3.1.1 Corrosion

Corrosion is the deterioration of a solid body through interaction with its environment, that is, destruction through unintentional chemical or electrochemical reaction beginnings at its surface.<sup>4</sup> Both metals and nonmetals are covered by this definition, Usually, the term "corrosion" describes the deterioration of paint and rubber by sunlight or chemicals as well as the destruction of metals.

There are several scenarios in which steel will corrode. These include physical contact with dissimilar metals (galvanic corrosion), stray currents from electrical machinery, small variation in the electric potential of the surrounding environment, and bacterial environment. The varying corrosion rates to be expected at differing levels of coastline have been generalized in Figure 2-2.<sup>4</sup> Two examples given are illustrations 3-2 & 3-3 of the corrosion of a steel H-pile and of steel sheet piles, respectively.<sup>3</sup>

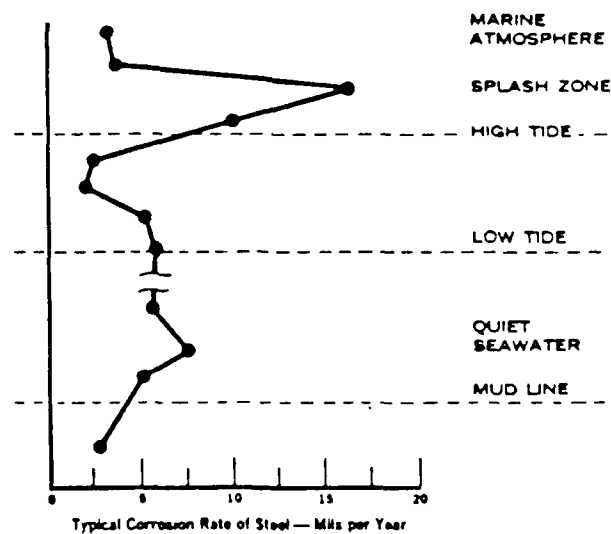


Figure 2-2 - Typical corrosion rates for steel at various depths in seawater (Ref. 4).

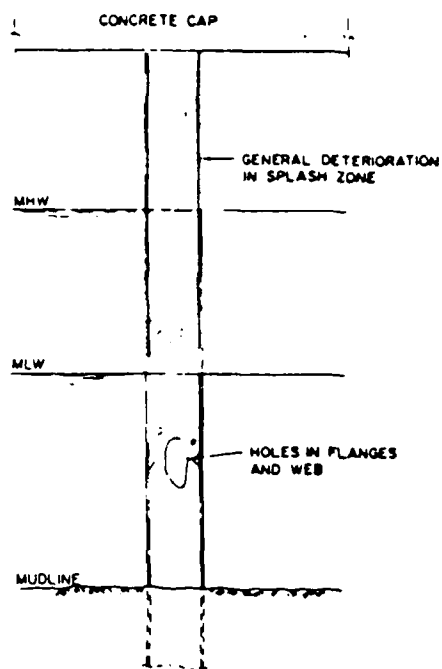


Figure 2-3 - Corrosion of steel H - pile (Ref.3).

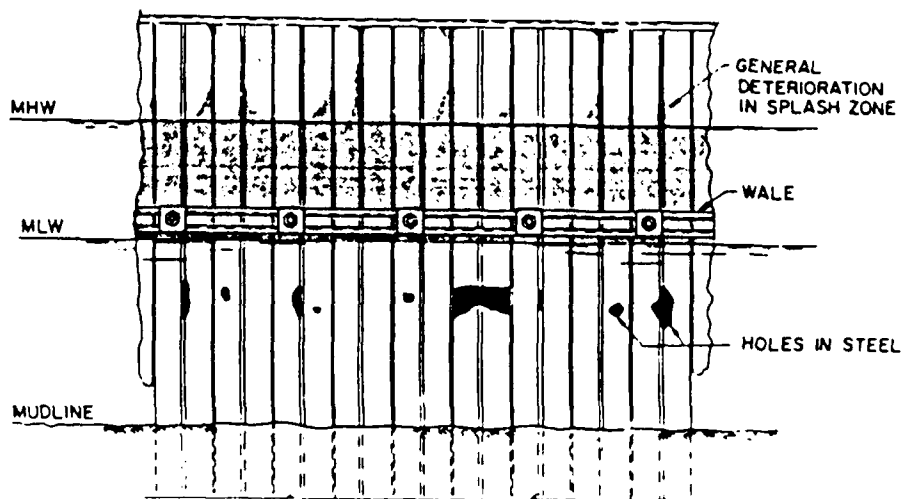


Figure 2-4 - Corrosion of steel sheet piles (Ref.3).

Bacterial corrosion or anaerobic corrosion, caused by sulfate-reducing bacterial is usually found in areas subject to lack of oxygen, such as inside steel pipe piles that are not filled with concrete.<sup>3</sup> This type of corrosion is more likely to be found in polluted harbors and is generally restricted to steel members that are buried below the mudline. Figure 2-5 illustrates bacterial corrosion (Ref. 3).

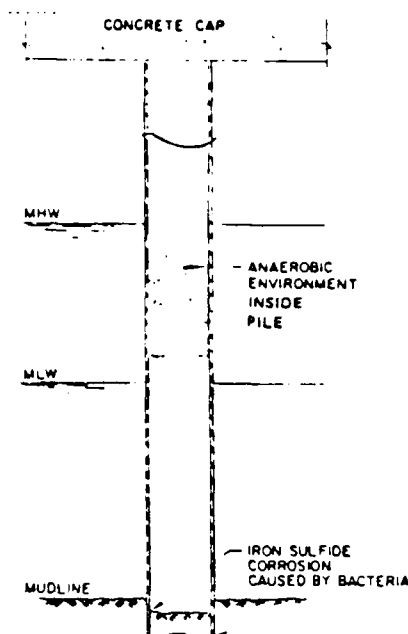


Figure 2-5 - Anaerobic corrosion of steel pipe piles (Ref.3).

#### 2.3.1.3.1.2 Erosion

If the flow of liquid over a metal surface becomes turbulent, the random liquid motion impinges on the surface which removes a semiprotective film of liquid molecules at the surface/liquid interface. Due to the turbulence, additional oxidation occurs, combined with the film removal, accelerates the rate of corrosion. Usually, the final product of this occurrence is a pitted surface, which weakens the strength properties of the metal.

The presence of solid particles or gaseous bubbles in the liquid can accentuate the attack. Also, if the fluid dynamics are such that impingement or cavitation attack is developed, even more corrosion can occur.<sup>4</sup> Erosion or erosion-corrosion details that mechanism of accelerated attack associated with abrasion with suspended particles such as sand. Abrasion of steel structures is a problem because it removes both protective coatings and protective layers of corrosion products, thus accelerating corrosion. This type of corrosion is recognized by the physical properties of a worn, smooth, polished appearance of the surface.

#### 2.3.1.3.1.3 Structural Connections

Structural fasteners have been known to loosen during the life of the structure. This is usually brought about by irregular loading, such as a vessel docking against a pier or wharf fendering system. The cyclic action created by waves and machinery are methods in which the fastener may be loosened. Besides structural disassembly, fretting corrosion may be imparted upon mated surfaces.

The rapid localized corrosion that occurs on closely fitting surfaces in contact under a load and subject to small amplitude (i.e., chafing or vibrating motion) is termed fretting corrosion.<sup>4</sup> Fretting corrosion takes the form of local surface discoloration and deep pits. This can result in distortion and stress concentrations in framing members.

#### 2.3.1.3.1.4 Fatigue Failure

When a load is repeatedly applied and removed, with the number of repetitions running into the many thousands or up into the millions, metal may develop cracks that eventually may spread to the point where they cause fatigue failure of the member.<sup>5</sup>

Fatigue cracks are usually hairline fractures perpendicular to the line of stress in the member. These fractures are found to occur more often when the repeated load is tension. Fatigue failure is more likely to occur in areas of local stress concentrations. Such concentrations may be due to poorly made welds, small holes, and rough or damaged edges resulting from the fabrication processes of shearing, punching, or poor-quality oxygen cutting. Tubular connections of offshore structures are particularly susceptible to fatigue failure. Figure 2-6 illustrates fatigue cracks on tubular steel members (Ref. 3).

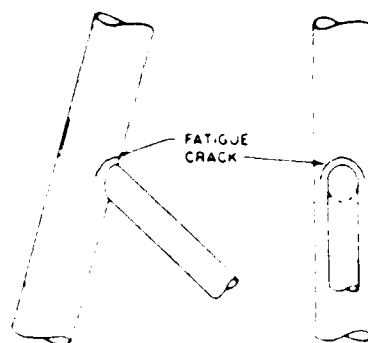


Figure 2-6 - Fatigue cracks on tubular steel (Ref.3).

#### 2.3.1.3.1.5 Overloading

Berthing vessels as well as any other type of loading can cause damage to sensitive elements of the structure. Usually, structural deformation occurs due to corrosion or impact loading. This type of damage is generally characterized by a sharp crimp or a warped surface as shown in Figure 2-7 (Ref. 3). Figure 2-8 illustrates a compression overload (Ref. 3).

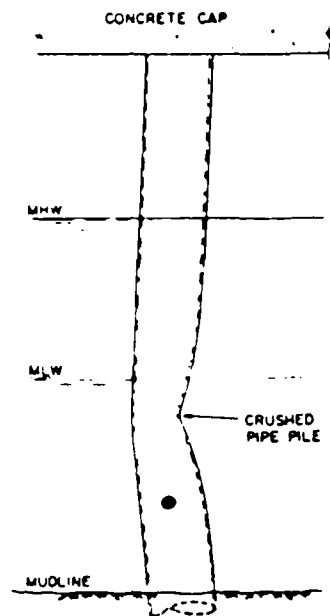


Figure 2-7 - Bending overloading of steel pile (Ref.3).

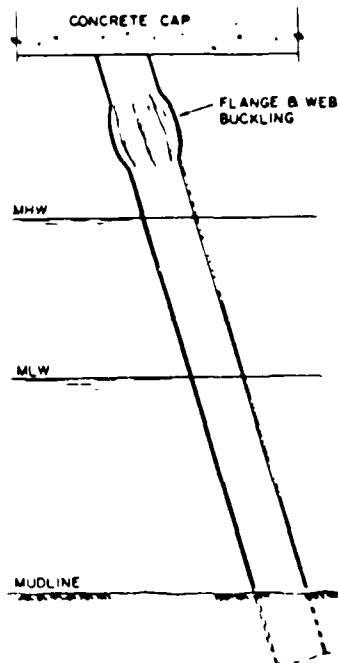


Figure 2-8 - Compression overloading of steel pile (Ref.3).

#### 2.3.1.3.1.6 Foundation Deterioration

Fixed waterfront as well as offshore structures are subject to scour. Scour is the removal of underwater material by waves and currents, especially at the base or toe of the structure. This can lead to accelerated corrosion of the exposed piles as well as decrease the load carrying capacity of the pile. If scouring is left unchecked, eventually the structure will fail. Figure 2-9 illustrates scouring (Ref. 3).

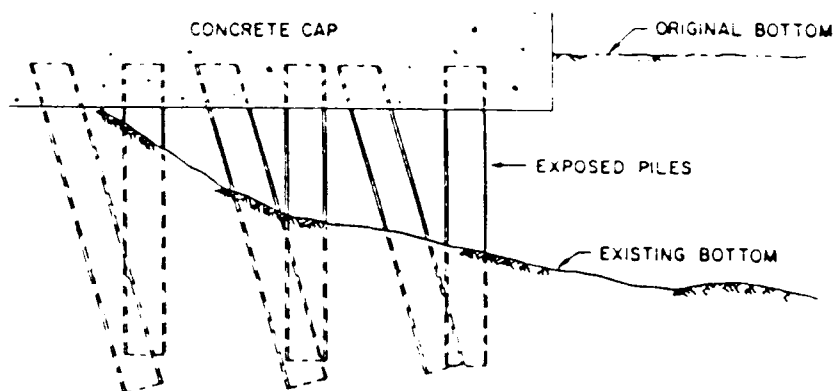


Figure 2-9 - Foundation loss (Ref. 3).

#### 2.3.1.3.2 Deterioration Of Concrete Structures

The choice of load bearing pile material in seawater has been reinforced or prestressed concrete. It provides high capacity, rigidity, dimensional flexibility, long life and low cost. With the proper concrete mixture, a life of 50 years is commonly attainable.

Eventually, concrete is attacked at the waterline. The leaching action of endless cycles of wetting and drying breaks down the chemical bonds that hold the materials together. Saltwater and pollution aid the process of deterioration.

Much of the concrete deterioration which is experienced is caused by corrosion of the steel reinforcing bar. The concrete cracks due to the expanding corrosion product (six times the volume of the metal from which it is formed), creating a higher corroding potential since the rebar is exposed to the atmosphere.<sup>4</sup> Cracks appear on the surface parallel to the direction of the rebar. Complete deterioration of the local area soon follows.

The following section will briefly discuss several methods of concrete deterioration.

#### 2.3.1.3.2.1 Freezing - Thawing Cycles

This is the freezing of absorbed moisture or water in porous concrete exposed to subfreezing temperatures.<sup>3</sup> Due to expansion - contraction cycles, the concrete begins to crack and disintegrate. Figure 2-10 illustrates a deteriorated concrete pile due to freeze/thaw cycling (Ref. 3).

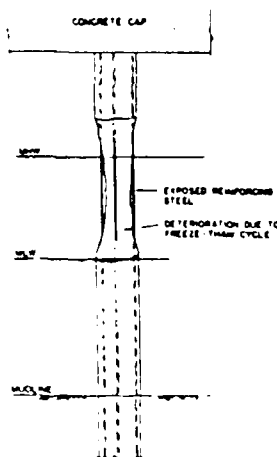


Figure 2-10 - Weathering of concrete pile (Ref.3).

#### 2.3.1.3.2.2 Abrasion

As with steel, solid particles or gaseous bubbles suspended in the flow of liquid accentuate the attack upon the concrete pile. As the concrete is worn away by erosion, the rebar is exposed creating a greater area for corrosion and structural failure. Figure 2-11 illustrates the effect of erosion upon a concrete pile (Ref. 3).

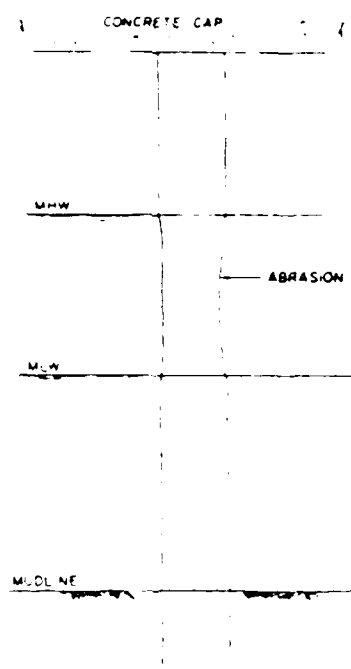


Figure 2-11 - Abrasion of concrete pile (Ref.3).

#### 2.3.1.3.2.3 Chemicals

Inorganic bonds of the cement binder broken by environmental agents will create corrosion of the concrete. Sulfates, ammonium salts, strong alkalies, weak acids, organic esters, carbon dioxide, magnesium salts, and many other agents can destroy the binder over a period of time.<sup>4</sup>

#### 2.3.1.3.2.4 Overloading

If the load is greater than the design load bearing pile, possible failure could occur. Pile driving can also impart an axial loading. This, as well as operational overloading, can impart stress factors along the pile. Figure 2-12 illustrates stress fractures formed on an overloaded concrete pile (Ref. 3).

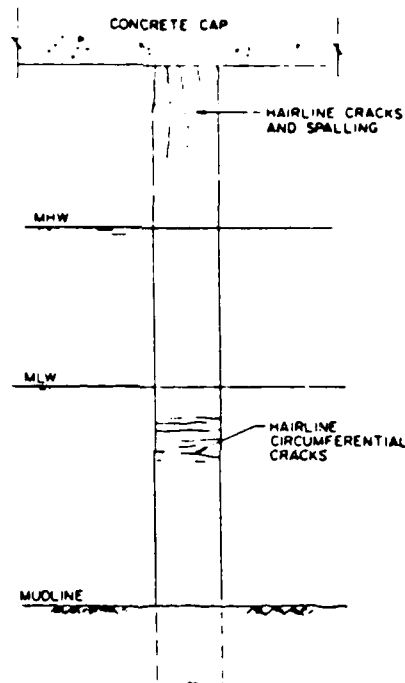


Figure 2-12 - Overloading of concrete pile (Ref.3).

#### 2.3.1.3.3 Deterioration Of Timber Piles

The deterioration of timber pilings can be attributed to several causes, but the most common is attack by marine borers and fungi in the tidal zone. Other types of deterioration are caused by termites, splitting due to wet/dry cycles, overloading and abrasion.

### 2.3.1.3.3.1 Marine Borers

There are two main groups of marine borers: crustaceans and mollusks. The limnoria, also known as woodgubbles, are the primary crustacean borer, while the terridines and pholads, also known as shipworms, are two groups of the mollusk borers. Figures 2-13, 2-14 and 2-15 illustrate the physical properties of the borers as well as the damage that can be inflicted (Ref. 11).

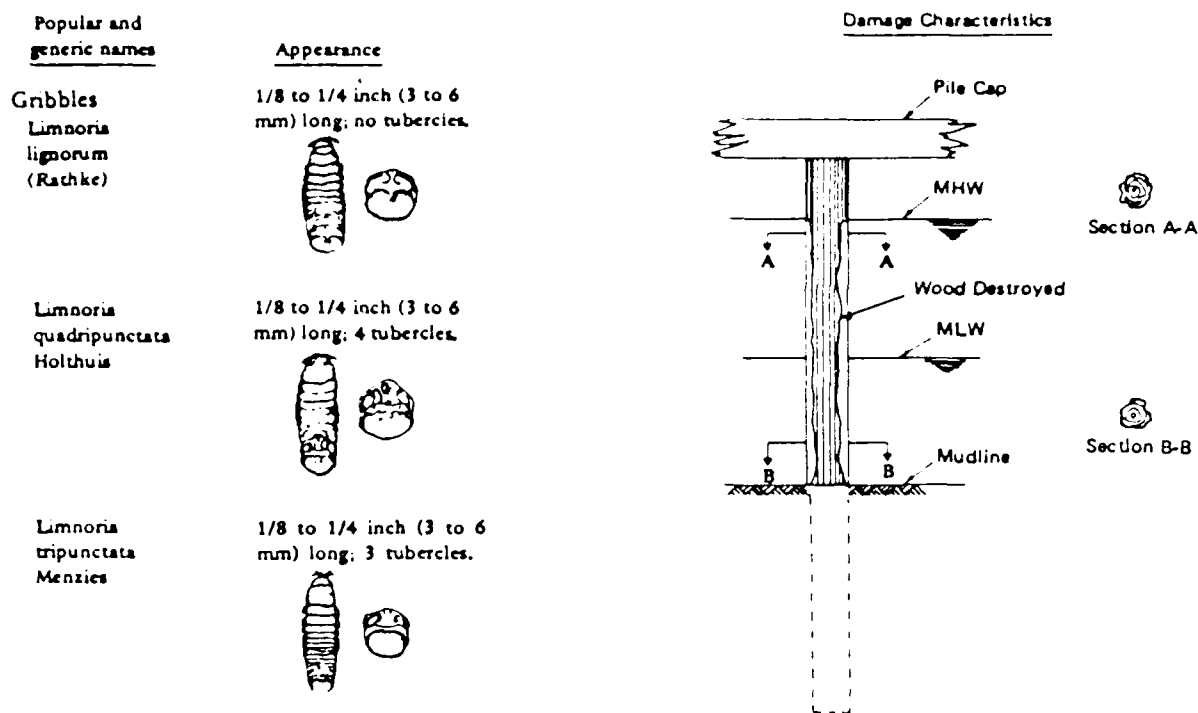


Figure 2-13 - Limnoria and Timber Damage Characteristics (Ref. 11).

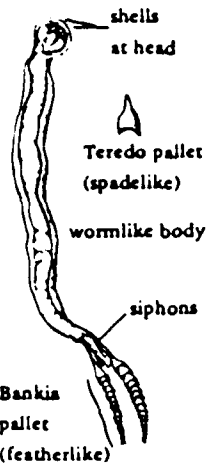
Popular and  
generic names

Appearance

Damage Characteristics

Shipworms  
*Teredo*  
*navalis*  
Linne'

Adults can grow 1 to 2  
feet (30.5 to 70 cm)  
long; 1/4-inch (12 mm)  
diameter.



*Bankia*  
*setacea*  
Tryon

Adults can grow 5 to 6  
feet (1.5 to 1.8 m)  
long; 7/8 inch (22 mm)  
diameter.

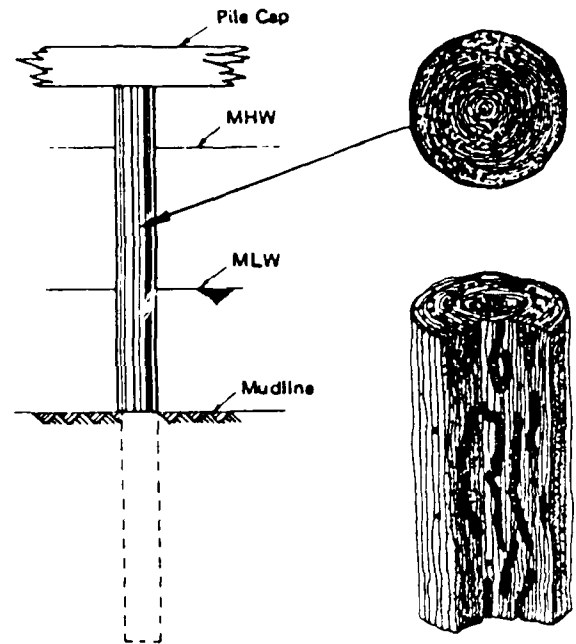


Figure 2-14 - *Teredo* and *bankia* and timber damage characteristics (Ref. 11).



(a) Pholads (*Martesias*  
*striata* Linne)



(b) Damage Characteristics

Figure 2-15 - Pholads and timber damage characteristics (Ref. 11).

Marine borers prefer an environment which contains a high level of dissolved oxygen and warm water temperatures. The following Table 2-1 gives a geographic distribution.

#### 2.3.1.3.3.2 Fungi And Rot Damage

Rot destroyed wood is evidence that some type of fungi is present. Fungi are lower forms of plant life which rely on the organic cell structure of the timber for food. In the early stages, fungi attack is evident by discoloration and softening of the wood accompanied by a fluffy or cottony appearance.<sup>11</sup> As the attack progresses, fungal colonies appear on the rotting timber. Environmental factors which influence the growth of fungi in a saltwater environment are a moisture content of over 20 % and temperature range of 50 to 90 degrees fahrenheit.

#### 2.3.1.3.3.3 Insects

The most wood destructive insect is the termite which attacks above waterline. This insect feeds on cellular matter contained in timber. Termites destroy the timber by digesting all wood particles on the interior to just inside the interior/exterior boundary of the pile. This is due to their dislike of light. Timber usually subject to attack are placed in, on or a few inches from the soil.

#### 2.3.1.4 Damage Of Fendering System

Fendering systems are designed to absorb energy being transferred from the docking vessel to the stationary pier. Therefore, to properly design a fendering system, energy loads of ships being used for cargo handling must be analyzed. This is to assure that large energy loads are not transferred to the waterfront structure. If a docking vessel transfers a large energy load of which the fendering system cannot totally absorb,

then structural damage will occur.

### 2.3.1.5 Accidental Disasters

Major accidents which occur at waterfront facilities vary upon the nature, magnitude, and location of the incident. Previous incidents have been limited to large explosions due to the transportation of volatile material. The area of destruction that surrounds the point of explosion is almost invariably enlarged by uncontrollable fires ignited as a consequence of the explosion.<sup>1</sup> Induced damage is pier deformation, destruction of cargo and cargo handling equipment (e.g., cranes, forklift trucks, etc...) and ships may be torn from moorings in which more damage could occur from collision with the facility or other vessel.

Table 2-1 - Geographic location of borers.

Species	Atlantic Coast	Gulf Coast	Pacific Coast	Pacific Area
<u>Limnoria tripunctata</u> (this species attacks creosote treated wood)	Massachusetts to the Caribbean; Canal Zone	Florida to Texas	San Francisco to Mazatlan (specimens collected here but southward limit not defined)	Hawaii, and other islands in the central and south Pacific
<u>Limnoria quadripunctata</u>	Bermuda	None reported on Gulf coast of the United States	California	Philippines
<u>Limnoria lignorum</u>	Maine to Florida	Florida, Texas	Alaska to Canal Zone	Philippines, Japan
<u>Teredo</u> (various species)	Entire	Entire	Entire	Entire
<u>Bankia</u> (various species)	Massachusetts to the Caribbean; Canal Zone	Florida to Texas	Adak to Canal Zone	Hawaii, and other islands in the central, south, and western Pacific
<u>Martesia striata</u>	North Carolina to Florida; Canal Zone	Florida, Texas	None reported on west coast of the United States	Hawaii, Guam, Philippines, Japan

Waterfront facilities that experience massive explosions without forewarning, usually disables the port completely until restoration construction is accomplished. This differs from simple pile failure in which the facility is still operable except at a lower degree. Debris removal is a major task, together with the extinguishing of fire and repair/replacement of facilities and equipment.<sup>1</sup>

The loss of ships, waterfront facilities, and equipment can total millions of dollars. This not only creates a tremendous economic impact, but also a logistics impact upon maritime operations as well. The degree of organization of rehabilitation effort and the availability of manpower, material, and financial resources are essential factors in restoration.<sup>1</sup>

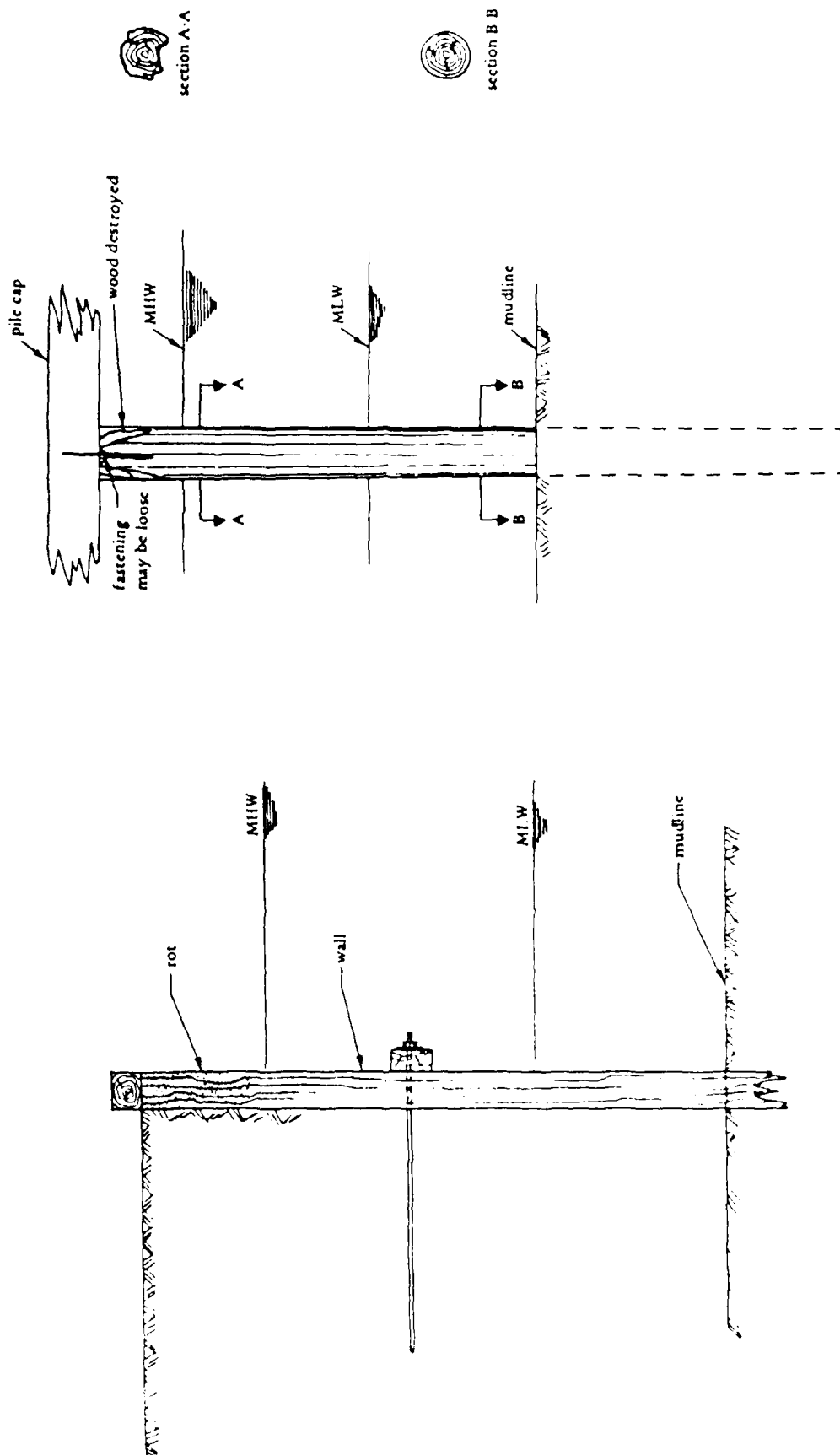
#### 2.3.1.6 Other Damage

There are several types of damage which occur to timber that also occurs to steel and concrete piles. These damages consist of: abrasion, overloading and connection corrosion.

As stated in previous text, abrasion is caused by the suspension of sand/silt particles in a moving current. If marine borers are present, then the process of abrasion damage is accelerated. Abrasion damage is illustrated in Figure 2-17.<sup>3</sup> To detect the difference between abrasion damage and woodgubbles, the pile will be worn to one side (direction of current). Also, abrasion usually leaves the surface fibers of timber piles rough and protruding from the surface of the sound timber.<sup>3</sup>

Damage occurs if the pile fibers are overloaded in the axial direction or a flexural moment is induced (Figure 2-18).<sup>11</sup> This damage can be caused by heavy cargo storage or ship impact from docking.

The weak link in marine timber construction is the connecting hardware, since the steel hardware is subject to corrosion.<sup>1</sup> The proper fasteners must be used or failure will cause the pile to displace. Figure 2-19 illustrates hardware failure.<sup>11</sup>



(a) Timber Wall

(b) Timber Pile

Figure 2-16 - Rot damage (Ref. 11).

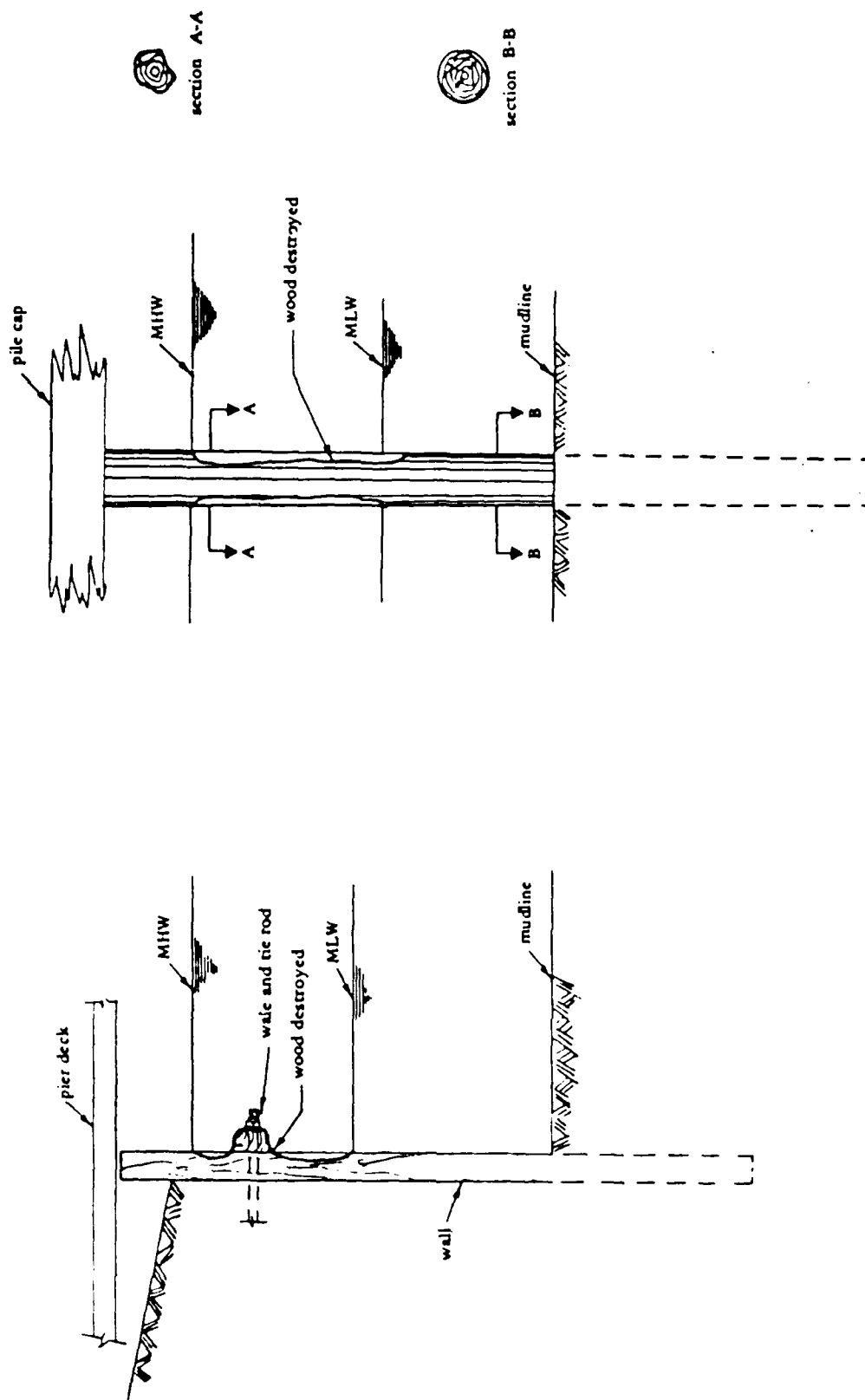


Figure 2-17 - Damage to Timber Construction as a Result of Abrasion (Ref. 11).

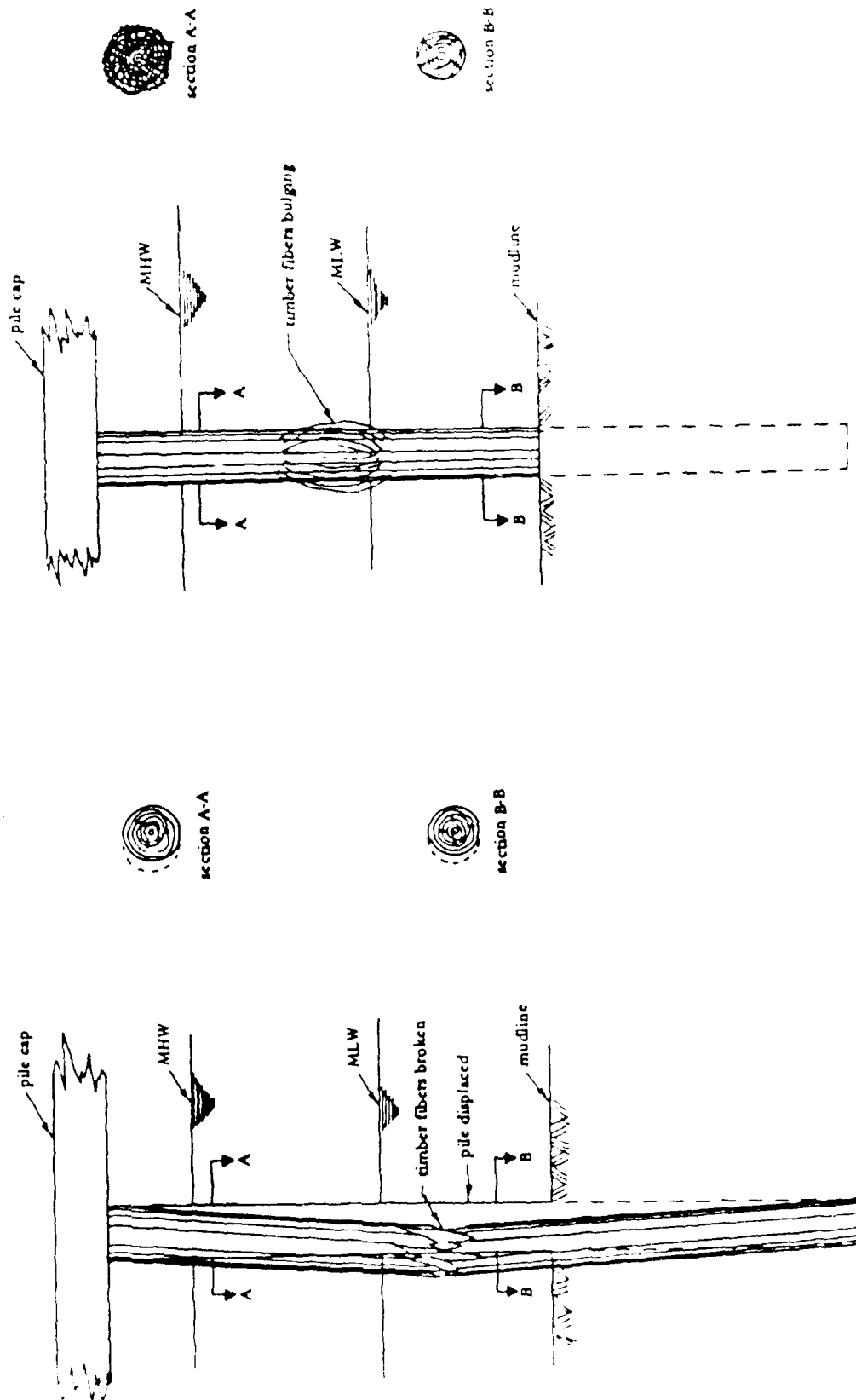


Figure 2-18 - Examples of Damage Resulting From Overloading Timber Member (Ref. 11).

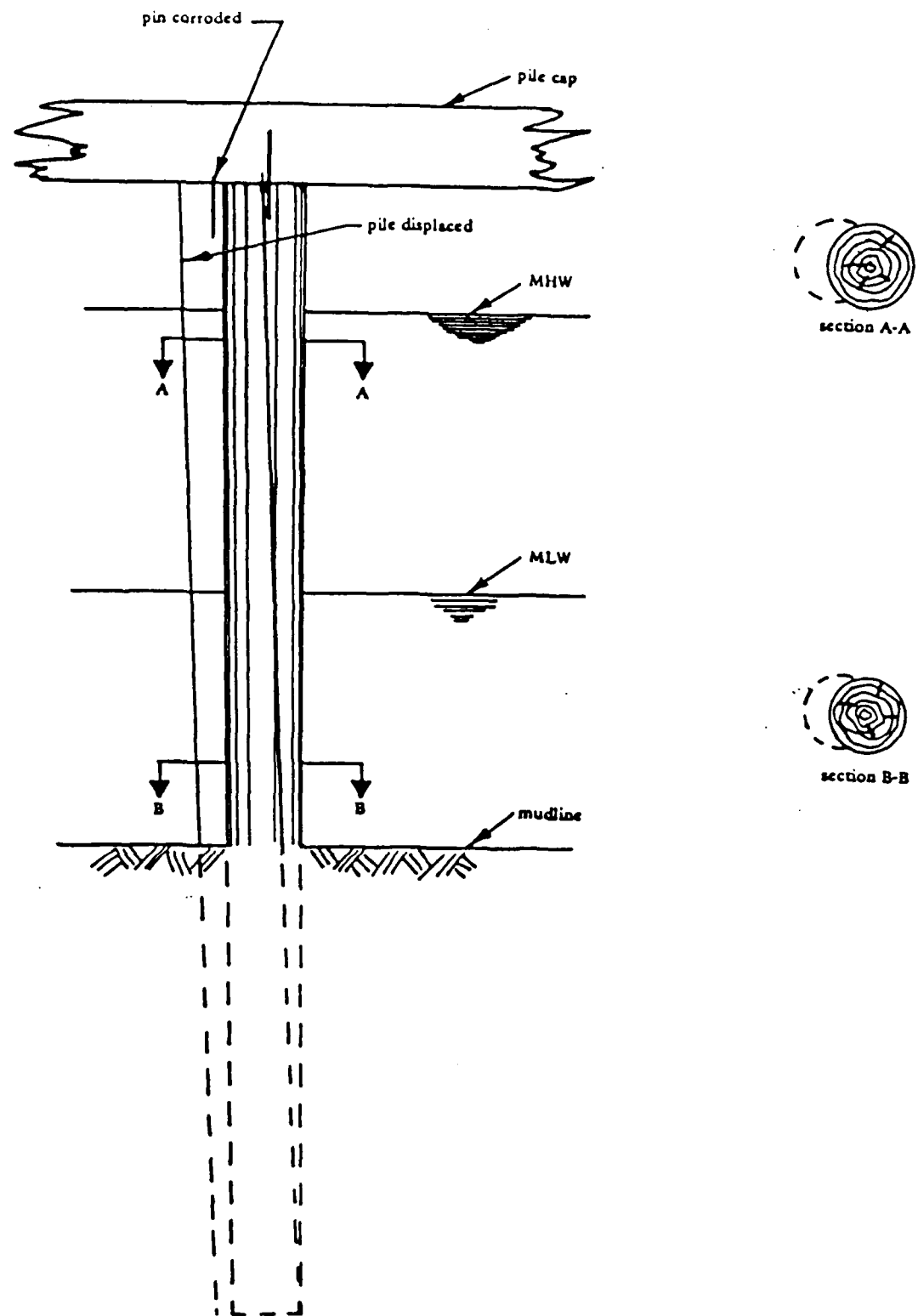


Figure 2-19 - Connection Failure in a Timber Structure (Ref. 11).

## 2.4 DAMAGE ASSESSMENT

In the event that damage by military or natural forces occurs to an advanced waterfront facility, a rapid repair and recovery capability is needed. The capability to load and unload vessels rapidly is a critical requirement. If this capability is decreased or prevented in either time or quantity, it is a severe handicap. In an advanced waterfront, the ability to rapidly assess and repair damage is essential.

If some type of damaging force, such as military or natural cause, afflicts the facility not only will the structure obtain damage, but repair equipment may be damaged or destroyed and key personnel injured. Rapid damage assessment is required to determine the extent and nature of the damage. To restore total operational capacity, damage repair must be expeditiously executed.

The proposed concept for post damage planning and execution is to develop a damage control process. This process will provide for the rapid assessment, prioritization, scheduling, and execution of expedient and semipermanent repairs. Figure 2-20 illustrates the decision process for waterfront damage repair.

### 2.4.1 Field Inspection

The purpose of any inspection is to provide the information necessary to assess the condition (capacity, safety, and rate of deterioration) of a structure.<sup>11</sup> Therefore, a structural inspection above or below the waterline should be considered a condition survey. All data obtained by the inspector should be supplied to an engineer to make the engineering assessment.

Three basic types of inspection have been developed in the North Sea for offshore structures. They are dependent upon

equipment availability, type of damage, and preparation needed.

The following is from Reference 11:

**Level I - General Visual Inspection:**

This type of inspection does not involve cleaning of any structural elements and can therefore be conducted more rapidly than the other types of inspection. The purpose of the Level I inspection is to confirm as-built structural plans, provide initial input for an inspection strategy, and detect obvious damage due to overstress, impacts, severe corrosion, or extensive biological attack.

**Level II - Close-Up Visual Inspection:**

This type of inspection will generally involve prior or concurrent cleaning of part of the structural elements. The purpose of the Level II inspection is to detect surface damage that may be hidden by marine growth. Since the cleaning process will make this type of inspection more time consuming than the Level I inspection, it will generally be restricted to the critical areas of the structure.

**Level III - Nondestructive Testing:**

This type of inspection will be conducted to detect hidden or beginning damage. The training, cleaning, and testing requirements will vary depending on the type of defect/damage that is anticipated and the type of inspection equipment used. In general, however, the equipment and test procedures will be more sophisticated and require considerably more experience

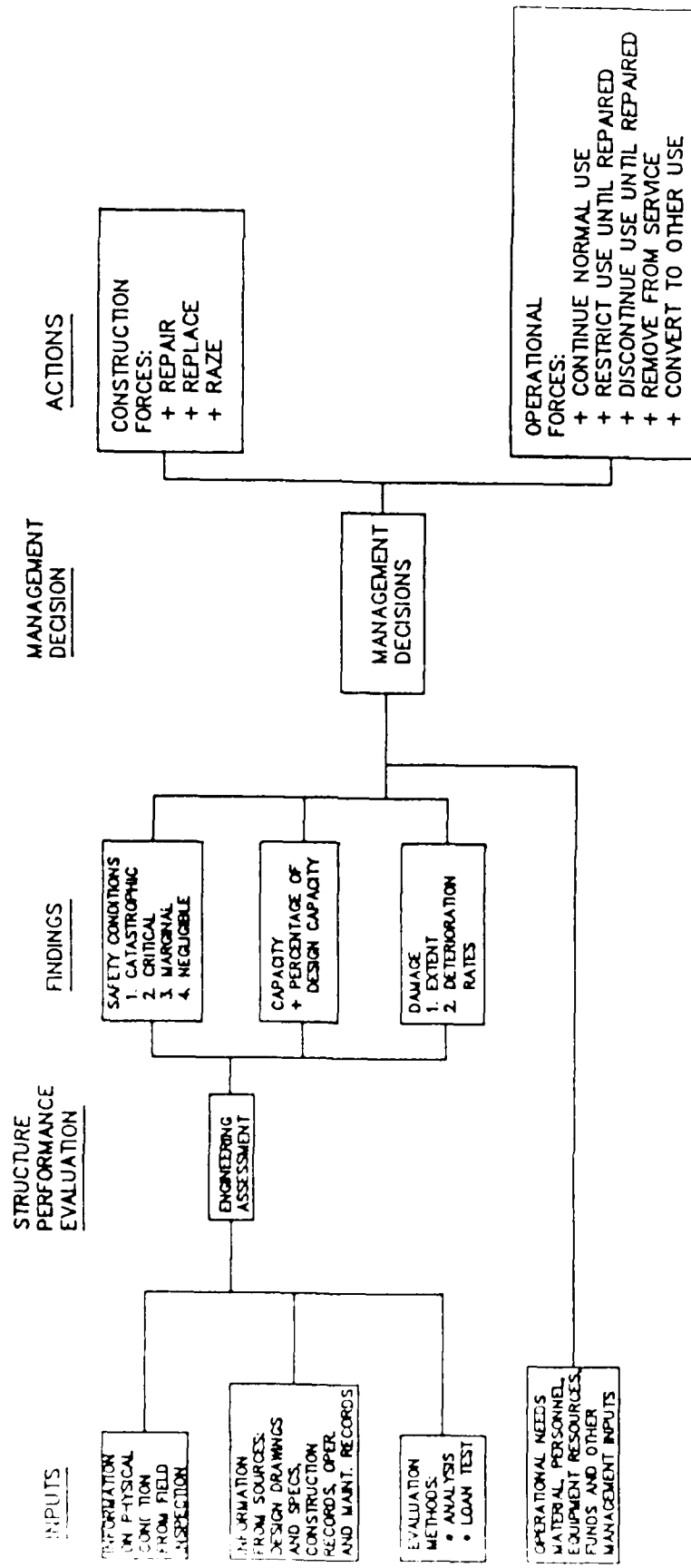


Figure 2-20 - Decision process for waterfront damage repair

and training than either the Level I or Level II inspection.

The following Table 2-2 is a culmination of types of detectable damage versus level of inspection.<sup>3</sup>

Table 2-2 - Detectable defects versus inspection level (Ref. 3).

Level	Purpose	Detectable Defects		
		Steel	Concrete	Wood
I	General visual to confirm as-built condition and detect severe damage	Excessive corrosion  Severe mechanical damage	Severe mechanical or ice (freeze/thaw) damage	Severe damage due to marine borers  Mechanical overload resulting in broken piles  Severe abrasion
II	Detect surface defects normally obscured by marine growth	Moderate mechanical damage  Corrosion pitting	Surface cracking due to mechanical overload  Deterioration of concrete due to sulphate action, moderate freeze/thaw damage, etc.  Severe corrosion of rebar  Spalling of concrete surface	External damage due to marine borers  Splintering due to mechanical overload
III	Detect hidden and beginning damage	Thickness of material	Location of rebar Beginning corrosion of rebar  Internal voids Change in material strength	Internal damage due to marine borers (internal voids)  Decrease in material strength

Table 2-3 is an estimation of minimum inspection time required to conduct Level I and II inspections upon structural elements.

Table 2-3 - Production rate for inspection  
of structural elements (Ref. 3).

Structural Element	Inspection Time Per Structural Element	
	Level I (min)	Level II (min)
12-in. steel H-pile	5	30
12-in.-wide strip of steel sheet pile	3	15
12-in. square concrete pile	4	25
12-in.-wide strip of concrete sheet pile	3	15
12-in.-diam timber pile	4	20
12-in.-wide strip of timber sheet pile	3	15

Waterfront facilities which are constructed of either wood, concrete, steel or a combination of these materials, have a large percentage of the structural elements below the surface of the water. Therefore, inspection techniques must be compatible with water environment. Table 2-4 gives a listing of nondestructive testing techniques that are used.<sup>11</sup>

Table 2-4 - Nondestructive Testing Techniques (Ref. 11)

General Techniques
Ultrasonic
Radiography
Vibration Analysis
Acoustic Emission
Steel Structures
Magnetic Particle
Eddy Current
Electrical Potential
Concrete Structures
Surface Hardness
Rebound Hammer
Penetration Techniques
Pullout Techniques
Magnetic Rebar Detection
Coring
Timber Structures
Increment Bores
Passive Sonic

Numerous techniques have been developed for nondestructive testing of materials either in laboratories or factories, however only five have found application in underwater inspection to date. These methods are (Reference 12):

- (1) Ultrasonic Testing (UT): This method uses the measurement of the transit time of high frequency sound waves to detect metal thickness and internal defects. Two measurement techniques are commonly used, (a) pulse/echo measurements in which a single transducer may be used to both send and receive signals transmitted into the test material and (b) transmission measurements where separate transducers located on opposite sides of the structure are used to send and receive the ultrasonic signal. The pulse/echo system

is most commonly employed in testing of metal structures while transmission techniques are applied to wood and concrete structures. Ultrasonic testing is best suited for the detection of internal planar defects and metal thickness. It can also be used to detect volumetric defects but considerable skill, training, and experience are required for the ultrasonic technician to obtain repeatable results.<sup>1</sup>

- (2) Magnetic Particle Inspection (MPI): The phenomenon of magnetic flux leakage is utilized in this technique to detect the presence of surface discontinuities (cracks) in metallic structures. A phosphorescent ink containing ferrous particles is applied to the surface of a structure in which an electromagnetic field has been induced. Cracks and surface discontinuities become visible when the area is illuminated by an ultraviolet light.
- (3) Radiography: The ability of various materials to absorb and scatter radiation is utilized in this method to produce a photographic image in which the variation in density of the developed film provides an indication of the thickness of the material being inspected. Since the source of radiation and the photosensitive film must be located on opposite sides of the object to be inspected, this technique is applicable only where both sides of the structure are accessible. Radiography is most often employed to detect volumetric defects in materials. Some success has been achieved in the detection of planar defects, however, the orientation of the major axis of this type of defect must be known as lined up with the path of the radiation in order to obtain acceptable results.

- (4) Eddy Current Testing (ECT): This method utilized information on the electrical conductivity, magnetic permeability and dielectric properties of metallic materials to detect cracks and measure wall thickness. A few experimental, underwater eddy current testing techniques have been demonstrated in the laboratory but to date it has not been used extensively to test structures in the ocean.<sup>2</sup>
- (5) Underwater Electrical Potential (UEP): This technique utilizes information about the difference in electrical potential between a metallic object and a silver/silver-chloride reference to determine the effectiveness of cathodic protection systems or identify the presence of local galvanic corrosion cells.

Of these five techniques, ultrasonics and radiography are not restricted by the type of material being tested while the other three may be used for testing metallic structures only. MPI is further restricted to detection of surface cracks of ferrous materials. These techniques may also be divided according to the type of defect detection for which they are primarily used. Radiography and ultrasonics are most commonly used to detect internal defects and material thickness. Magnetic particle and eddy current techniques find their primary application in the detection of surface cracks, and electrical potential measurement is used only to determine the effectiveness of cathodic protection systems.

Table A-1 indicates the potential applicability of these NDT techniques for inspection of typical waterfront structures, materials and possible types of defects.

Although visual inspection is not normally classified as a non-destructive testing technique, it can yield valuable information about the condition of a structure without adversely affecting its integrity. Due to the diverse nature and methods used to conduct visual inspections, this technique will not be discussed in detail in this report. It should, however, be given prime consideration when assessing the suitability of various techniques for conducting underwater inspections. An important requirement for most of these techniques is that the surface of the structure be cleaned of marine growth, loose scale, rust, and coatings such as paint or concrete. Without direct contact of the test equipment on the surface to be tested, little chance exists of obtaining valid (repeatable) results. Surface cleaning is an important facet of visual inspections as well and often becomes the critical path as far as time and cost of the inspection are concerned.

#### **State-of-the-Art of Underwater Nondestructive Testing**

To determine the state-of-the-art in underwater nondestructive testing, contacts have been made with diving contractors and equipment manufacturers in both the United States and Europe who are involved in underwater inspection. Visual inspection, with television and still camera documentation, is by far the most commonly used technique in the United States, while in Europe NDT techniques have been used more extensively due to regulations governing the certification of offshore structures in the North Sea areas. The U.S. companies which offer underwater NDT services tend to use ultrasonics and radiography, while in the North Sea area magnetic particle and ultrasonic inspections are the most common. There does not appear to be any significant difference in the level of development of equipment currently used in Europe or the U.S., however, the use of NDT equipment is much more widespread in Europe. These government regulations have also lead to a much greater emphasis on developing

standardized techniques for conducting inspections and has spurred considerably more research in the field of underwater NDT in Europe than in North America.

### Ultrasonics

The use of ultrasonics to inspect steel structures is usually divided into two categories: thickness measurements and flaw detection. By far, the most common application of underwater ultrasonics inspection encountered was for thickness measurement of pipelines and risers.

The newest type of inspection is the use of Remotely Operated Vehicles (ROVs). These vehicles are unmanned and carry singly or in combination: cameras, propulsion systems, lights and manipulators. They are linked either to the surface or to a manned submersible by tether and wiring that carries the video and operational signals to and from the ROV.

One of the newly developed systems is labeled Jason Jr.(J.J.). This is a small vehicle with a full axis propulsion system that enables it to swim free, controlled by an operator either on the surface or in a submersible. This prototype carries a live television imaging system and lights on board, thereby coupling its ability to maneuver in tight spaces with its ability to project live images. Figure 2-21 illustrates the design of Jason Jr. by the Deep Submergence Laboratory in Woods Hole Oceanographic Institution.<sup>7</sup> The concept of a ROV for inspection purposes could be very useful. A ROV of this type is too sophisticated and costly for underwater inspection of waterfront facilities. A simplified version would be more useful.

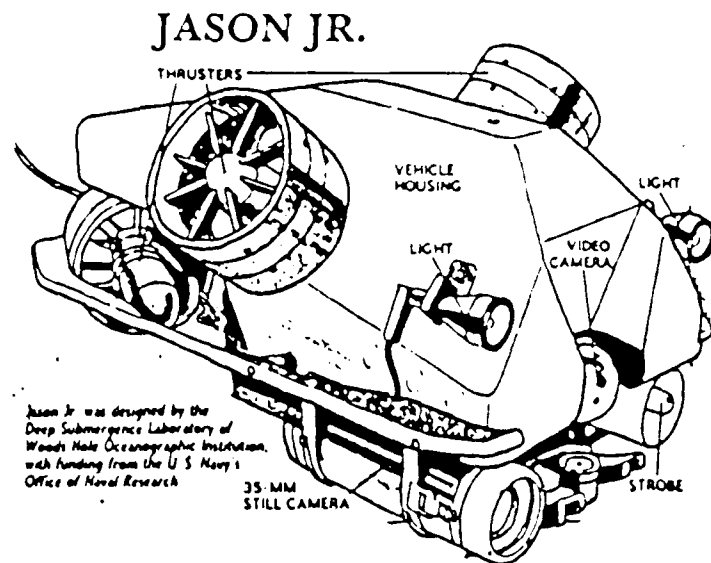


Figure 2-21 - ROV Jason Jr. (Ref. 7).

#### 2.4.2 Inspection Documentation

The objective of the inspector is to document the findings in a clear and concise manner for later analysis. In the process of documentation, the use of a standard format of reporting will greatly reduce the time to assess the information, especially if there are several investigators. Figure 2-22 illustrates a standard form for reporting pile condition.<sup>3</sup> The inspection

record contains a section for pile condition ratings. Figure 2-23 and Figure 2-24 describe pile condition ratings for concrete piles and wood piles, respectively.<sup>3</sup> Steel pile inspection results are usually recorded in terms of remaining metal thickness.

The following is an excerpt from Reference 12 that details use of photography for documentation. This should be done both above and below the waterline.

Whenever appropriate, visual inspection should be documented with still photography and closed-circuit television. Still photography provides the necessary high definition required for detailed analysis, while video, though having a less sharp image, provides a continuous view of events that can be monitored by surface engineers and recorded for later study. All photographs should be numbered and labeled with a brief description of the subject. A slate or other designation indicating the subject should appear in the photograph. When color photography is used, a color chart should be attached to the slate to indicate color distortions. Video tapes should be provided with a title and lead-in describing what is on the tape. The description should include the method of inspection used, the nature and size of the structure being inspected, and any other pertinent information.

A debriefing with the activity personnel, with slides or photographs, should be conducted before leaving the site, and all questions should be resolved.

[illegible]

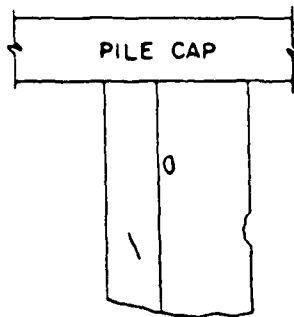
CONCRETE PILE  
CONDITION RATING

EXPLANATION

NI NOT INSPECTED, INACCESSIBLE OR PASSED BY

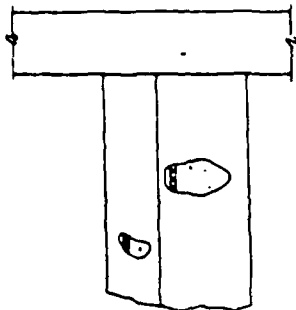
NC NO DEFECTS:

- fine cracks
- good original surface, hard material, sound



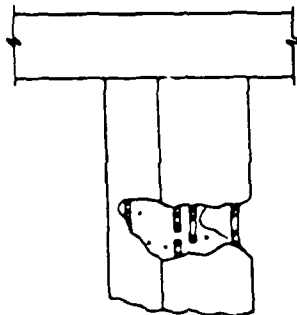
MN MINOR DEFECTS:

- good original section
- minor cracks or pits
- surface spalling that exposes coarse aggregate
- small chips or popouts due to impact
- slight rust stains
- no exposed re-bar
- hard material, sound



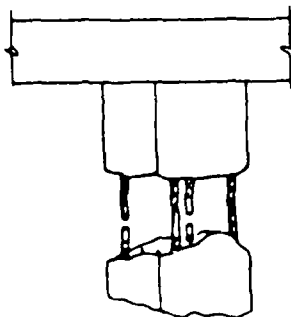
MD MODERATE DEFECTS:

- spalling of concrete
- minor corrosion of exposed re-bar
- rust stains along re-bar with or without visible cracking
- softening of concrete due to chemical attack
- surface disintegration to one inch due to weathering or abrasion
- reinforcing steel ties exposed
- popouts or impact damage



MJ MAJOR DEFECTS:

- loss of concrete (10-15%)
- one or two re-bars badly corroded
- one or two ties badly corroded
- large spalls six inches or more in width or length
- deep wide cracks along re-bar
- dummy areas full width of face



SV SEVERE DEFECTS:

- two or three re-bars completely corroded
- no remaining structural strength
- significant deformation

Figure 2-23 - Explanation of Pile Condition Ratings for Concrete Piles (Ref. 3).

TIMBER PILE  
CONDITION RATING

EXPLANATION

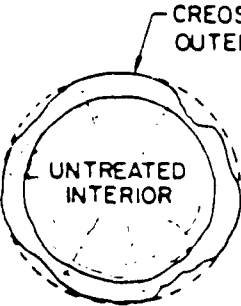
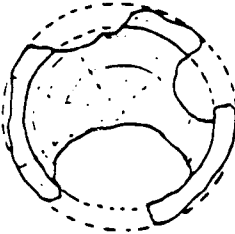
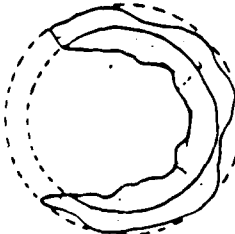
	NI	NOT INSPECTED, INACCESSIBLE OR PASSED BY
	ND	NO DEFECTS: - less than 5% lost material - sound surface material - no evidence of borer damage
	MN	MINOR DEFECTS: - 5% to 15% lost material - sound surface material - no evidence of borer damage - minor abrasion damage
	MD	MODERATE DEFECTS: - 15% to 45% lost material - significant loss of outer shell material - evidence of borer damage - significant abrasion damage
	MJ	MAJOR DEFECTS: - 45% to 75% lost material - significant loss of outer shell and interior material - evidence of severe borer damage - severe abrasion damage
	SV	SEVERE DEFECTS: - more than 75% lost material - no remaining structural strength - severe borer damage

Figure 2-24 - Explanation of Pile Condition Ratings for Timber Piles (Ref. 3).

#### **2.4.3 Support Information for Inspection**

To investigate the problem to the fullest, all information pertaining to the facility should be obtained:

- o Drawings of the facility showing the original construction and any alterations.
- o Details of the facility (type of fleet moorings, materials used in the structure, use of the structure, etc...).
- o Operation and maintenance records.
- o Up to date charts and maps of the area.
- o Local tides, currents, water quality, winds, temperature, visibility and daylight hours.

The inspection should be performed in a manner with which the entire structure will be analyzed. This imparts inspecting a sufficient number of areas to provide representative information on the overall structure. From interpretation of the architectural/structural drawings, a trained investigator/engineer can determine areas subject to fatigue, stress, and impact forces. The overall information that is obtained is used to make a structural performance evaluation by the engineer(s).

#### **2.4.4 Evaluation Methods**

Evaluation methods are concerned with the structural analysis used to interpret findings from the field inspection. The criteria for such an analysis would be lengthy and beyond the scope of this report. Also, such an analysis would be dependent

upon several parameters: type of structure, extent and type of damage, material used, and environment location.

The analysis therefore accounts for the load forces for which the damaged structure is in contact. These loads are classified into two headings: dead and live loads.

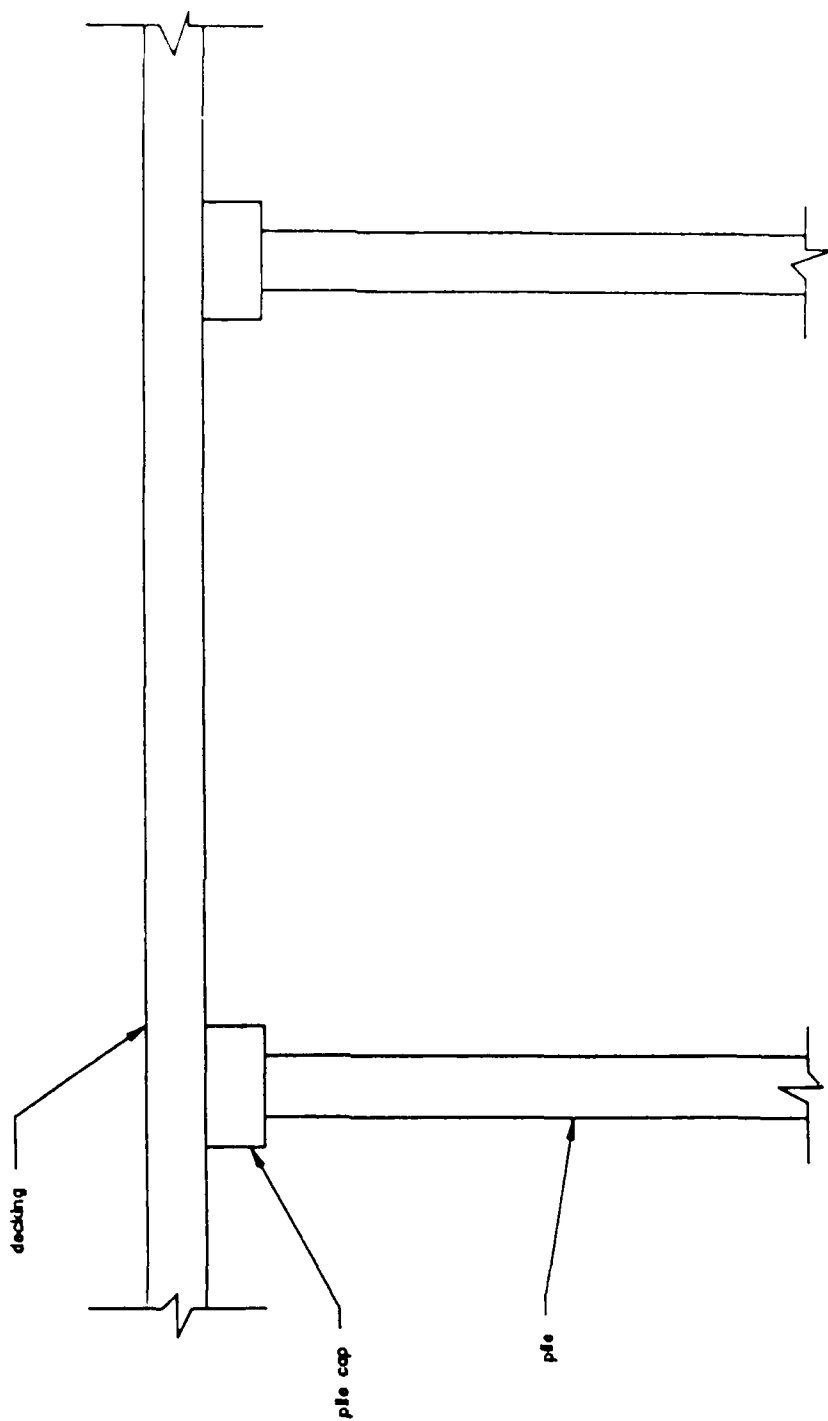
Dead loads include the weight of the structure, and any permanent material placed on the structure. Live loads consist of all things that are not dead loads. They may be steady or unsteady, moveable or moving; applied slowly, suddenly, vertically or laterally; and their magnitude may fluctuate with time. In general, live loads include:

- o Occupancy loads caused by weight of cargo.
- o The weight of snow if accumulation is probable.
- o Forces resulting from wind action and temperature changes.
- o The pressure of liquids or earth on retaining structures.
- o Dynamic forces resulting from moving loads (impact) or from earthquakes.
- o Forces resulting from blast loading.

These factors included with the transmitted loads from the damaged to the undamaged portion of the facility must be evaluated. From the analysis of the information gathered through field inspection, original drawings and specs, and the structural evaluation, the engineering assessment can be accomplished by the engineer.

#### 2.4.5 Extent of Capacity

Undamaged portions of a pier may experience capacity reduction due to a loss of support caused by adjacent damage. Damage can be considered to be a crater from a direct hit or a loss of a pile from naturally occurring damage. Take for instance, a one-way concrete slab design for a pier. One-way slab may be structurally classified as a slab which is supported on two opposite sides. The load will cause the slab to bend or deflect in a direction perpendicular to the support edges. The structural action is one-way, and the loads are carried by the slab in the deflected short direction. Figure 2-25 illustrates side view of a generic pier/wharf. Figure 2-26 shows the distribution loads on a one-way slab supported by pile caps (beams) and piles. The shaded area shows that each column carries loads from slabs surrounding the column and up to the centerline of adjacent slabs: up to  $L/2$  in the long direction and  $S/2$  in the short direction. Therefore the worst case damage scenario would be of a loss of a pile and pile cap. The adjacent structural area to the crater would have a capacity reduction because of the loss of support from steel rebars. A conservative method for estimating capacity, as recommended by Reference 9, is to assume that the remaining deck acts as a cantilever extending from the remaining intact pile caps. This, however, ignores the support that the undamaged area imposes upon the reduced capacity area. This method of analysis is good in the effect that a greater factor of safety is present because the analysis does not take into account the extra support. The determination of the extra support from the undamaged area is dependent upon thickness of concrete, reinforced steel design, and the geometry of the damaged area. The engineer making the assessment may want to check specific areas for their stability by load testing. This may be accomplished by using material at the waterfront such as: material for reconstruction or damaged material.



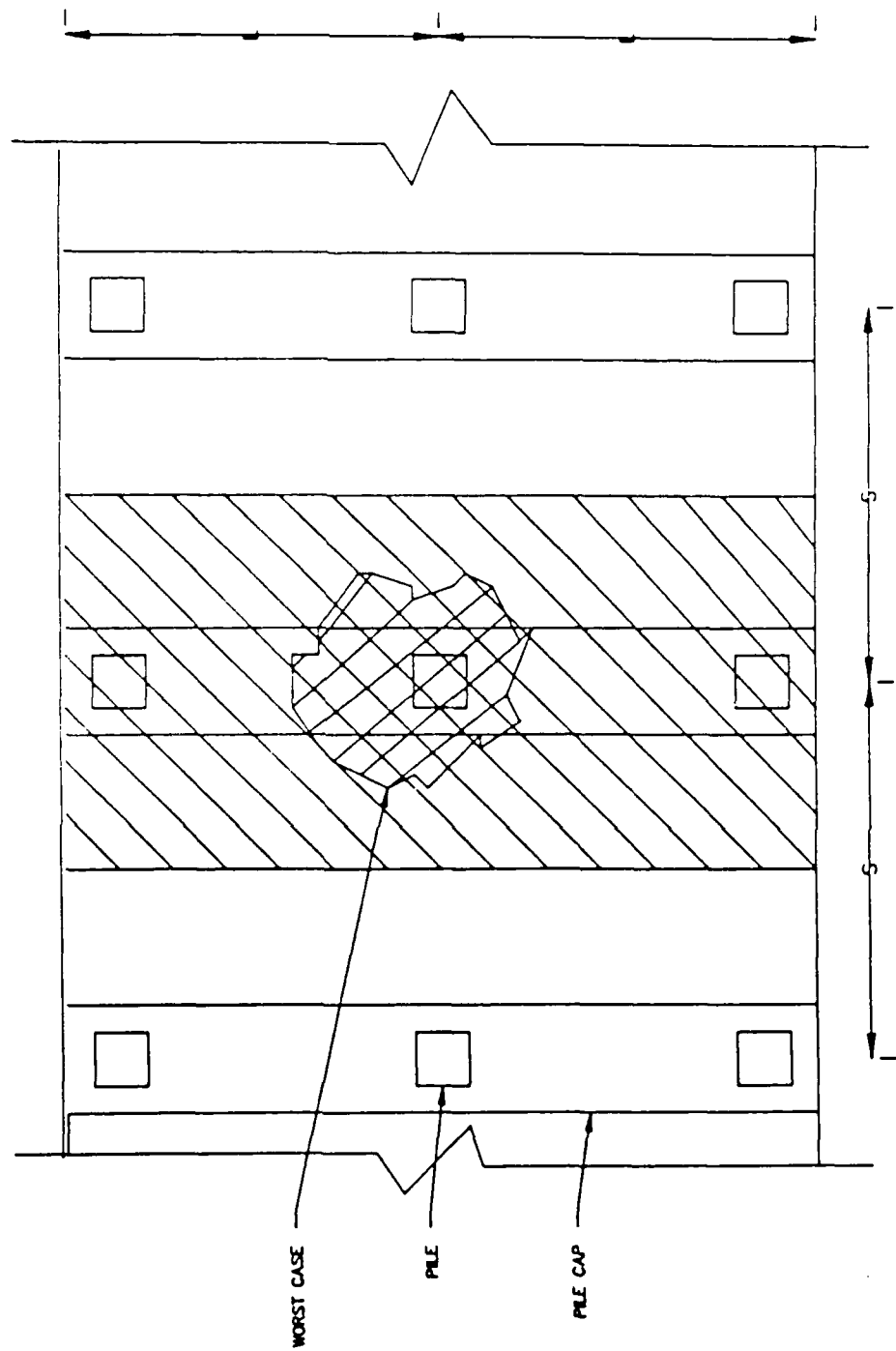


Figure 2-26 - Distribution of Loads on Pile Caps

#### 2.4.6 Safety

During the assessment, the structure's safety is determined. This is obtained in terms which will specify the conditions that can cause death, injury, damage or loss of equipment or structural components. The investigator must be concerned with analyzing the facility for hazards to personnel and equipment. The engineer applies methods of hazard identification and analysis, develop design criteria, review the design for compliance, and provide safety certification of equipment. Safety requirements and standards are applied to all operations. Safety critical items and operations are identified and controlled to reduce hazards to an acceptable level of risk.

In respect to the waterfront structure, there are four classifications of safety conditions:

- o Catastrophic
- o Critical
- o Marginal
- o Negligible

Each classification refers to the structures potential for collapse and likelihood of injury or death to personnel in respect of possible occurrence percentage. Requirements for a system safety program are defined in Military Standard MIL-STD-882A "System Safety Program Requirements".

#### 2.4.7 Deterioration

In the determination of the capacity of the structure, the extent and rate of deterioration can be obtained from inspection

and previous inspection reports. This information may be used to predict useful life of the structure and to estimate maintenance/repair actions needed for the structure to remain in a safe condition and to continue to provide the required capacity.<sup>9</sup> In the overall readiness planning, this information is used to create a strategy for resource allocation needed to maintain a specified operational capability and level of safety.

#### 2.4.8 Management

When all the data has been analyzed, the engineering assessment has been completed, a management decision will be made. This will determine the course of action to take in respect to the constructional aspect of the structure (repair, replace, or raze), and the operational aspect (continue normal use, to derate, to convert to other uses, etc...).

To determine the final outcome with the facility, other information is required. This entails the priorities of operation (its use in short and long range plans, etc...) and the effectiveness of the structure to meet these needs. Other information is analyzed before the final decisions are made, such as: time, manpower, equipment, materials, and weather.

In order to allow the most effective utilization of a damaged facility in the shortest period of time, repair and replacement of damaged areas must be given levels of importance. Level of importance is determined by several factors: operational needs, safety, prior operational capabilities, manpower, materials, and tool.

To determine the number of personnel to perform a task, an estimate of the time period to perform a unit work element is calculated. Using Table 2-5 through 2-14 from Reference 10, the number of man days per task can be obtained. These figures

are statistically obtained and therefore may change under differing conditions. Table 2-25 lists several factors for which the production may be effected.<sup>10</sup> Possible reasons are given to achieve low, average, and high productions.

To assist with the management decision process, the use of knowledge based expert systems could be incorporated into the damage assessment and repair program. The major contribution of a system of this type would be as a planning/training tool.

Expert system programs are developed to absorb previous and present information to form a data base by which specific information may be ranked. The information or "rules" are ranked by need, importance, and immediacy for decision-making.

In a waterfront damage repair scenario, the function of the expert system is to provide advice in certain situations. All the operator has to do is read the directions and follow the sequenced steps; the system can (1) advise the operator, (2) take over when the situation becomes an emergency, or (3) take over if human intervention fails.<sup>20</sup> Military application may further the use of expert systems by combining with planning/training programs. This would increase military personnel reaction times and dictate future policy with assessment and repair during simulated exercises rather than during actual conflicts.

The needs for an expert system are ranked as follows: (1)making quick decisions with a less than adequate amount of information available, (2)the analysis of on going functions, and (3)the complex tasks that require large amounts of time to rank and process the data.<sup>20</sup>

Table 2-5 - Wood Pile Dolphins (Ref. 10)

WORK ELEMENT DESCRIPTION	UNIT	MAN-HOURS PER UNIT
Place in Leads and Drive	Each	.8
Lash with Wire Rope	Each	.75
Install Fenders	Each	.8
Fender Pile	Each	.75

## NOTES:

1. Based on 50' piles

Table 2-6 - Piledriving (Ref. 10)

WORK ELEMENT DESCRIPTION	UNIT	MAN-HOURS PER UNIT
25' Wood Piling	Each	3
50' Wood Piling	Each	6.5
75' Wood Piling	Each	9.5
25' Steel Piling	Each	4
50' Steel Piling	Each	7.2
75' Steel Piling	Each	12
40' Precast Concrete Piling	Each	13.2
60' Precast Concrete Piling	Each	18
80' Precast Concrete Piling	Each	24
Steel Sheet Piling	1000 S F	102
Assemble and Rig Leads and Hammer	Each	48
Dismantle Leads and Hammer	Each	32

## NOTES:

1. Man-Hour figures are preliminary estimate only. The many variables of this work require on-site determinations for accurate estimates.

2. Factors of importance are Design, soil, equipment and method used, tides, access to site, currents, materials storage, etc.

3. Work included is preparation of pile, placing in leads, driving and cut off.

4. For concrete filled, fluted hollow steel piling and pipe piling for spudding pontoon smallcraft finger piers, use the steel bearing pile figures.

Table 2-7 - Pile Bracing and Capping (Ref. 10)

WORK ELEMENT DESCRIPTION	UNIT	MAN-HOURS PER UNIT
Diagonal Bracing	Each	6.5
Horizontal Bracing	Pair	8
Wood Caps	1000 LF	480
Concrete Caps	LF	3.2
Steel Caps	1000 LF	480

## NOTES:

1. Based on bolting or drilling members in place.

Table 2-8 - Pile Extraction (Ref. 10)

WORK ELEMENT DESCRIPTION	UNIT	MAN-HOURS PER UNIT
Wood Bearing Piles	Each	2
Wood Sheet Piling	1000 SF	24
Steel Sheet Piling	1000 SF	28
Piles Cut-Off Below Water Line	Each	2.5

## NOTES:

1. Based on using pile extractor.

Table 2-9 - Miscellaneous Pier Hardware (Ref. 10)

WORK ELEMENT DESCRIPTION	UNIT	MAN-HOURS PER UNIT
Bits	Each	13
Bollards	Each	16
Chocks	Each	13
Creels	Each	11
Pad Eyes	Each	2.5

Table 2-10 - Structural Steel Fabrication (Ref. 10)

WORK ELEMENT DESCRIPTION	UNIT	MAN-HOURS PER UNIT
FABRICATE: Structural Frames	Ton	16
Columns	Ton	16
Girders	Ton	16
Beams	Ton	10.4
Trusses	Ton	8
Purlins, Girts and Struts	Ton	12.8
Frames for Openings	Ton	2.8
Stairs	Ton	28
Platforms	Ton	36
Railings (Simple Tube Pipe)	10 Lin. Ft.	16

## NOTES:

- 1 Fabrication of structural steel includes cutting, riveting, burning, drilling, milling, fitting, assembling, welding, bolting, storing, loading, and hauling to the job site.
- 2 Man-hour units are based on bolted connections; if sections are to be welded, add 25 percent for welded joint preparation.

Table 2-11 - Reinforcing Steel Fabrication (Ref. 10)

MAN-HOURS REQUIRED FOR MAKING 100 BENDS OR HOOKS				
SIZE OF BAR IN INCHES	BY HAND		BY MACHINE	
	HOURS	HOURS	HOURS	HOURS
1/2" or Less	4	6	1.5	2.5
3/8", 1/2" and 5/8"	5	8	2	3
1" and 1 1/8"	6	10	2.5	4
1 1/2" and 1 3/4"	7	12	3	5

## NOTES:

- 1 Reinforcing steel fabrication includes cutting, bundling, lagging, Assembly and tying into mats and beams in the shop are also included.

Table 2-12 - Placing Reinforcing Steel (Ref. 10)

LABOR HOURS FOR PLACING 100 BARS			
	LENGTH OF BAR IN FEET		
	Under 10	10 — 20	20 — 30
1/2" or less	6	7	8
3/8", 1/2" and 5/8"	7	8	9.5
1" and 1 1/8"	8	10	11.5
1 1/2" and 1 3/4"	9	12	14
WELDED WIRE FABRIC	UNIT		MAN-HOURS
Slabs on Grade, Concrete Paving, Precast Roof Panels	100 SF		.8
Gunite and Head Walls	100 SF		1

## NOTE:

- 1 Placement of reinforcing steel includes handling into place, tying, supporting, and any cutting which becomes necessary at the site, such as cutting around embedded items or cutting stock lengths of straight bars to fit slab dimensions.
- 2 Man-Hour estimates are based on all reinforcing steel being shop fabricated (cut to length and bent ready to place in the structure).
- 3 If reinforcing steel is to be welded in place, add 50 percent to the time factor.

Table 2-13 - Structural Steel Erection (Ref. 10)

WORK ELEMENT DESCRIPTION	UNIT	MAN-HOURS PER UNIT
UNLOAD, ERECT AND PLUMB		
Columns	Ton	13.6
Beams	Ton	13.6
Girders	Ton	9
Trusses	Ton	17
Girts and Purlins	Ton	11.9
Bracing and Tiers	Ton	17.9
Light Framing	Ton	23.8
HIGH STRENGTH BOLTING	100 bolts	7.5
Grating	1,000 Sq. Ft.	192

## NOTES:

- 1 Erection of structural steel includes handling, erecting, temporary bolting, plumbing, leveling, high strength bolting and/or welding.
- 2 Man-hour figures are based on using new construction materials.

Table 2-14 - Welding Structural Steel (Ref. 10)

Per L.F. Material Thickness in Man Hours

	HORIZONTAL	VERTICAL	OVERHEAD
Field Arc Welding			
1/8"	.15	.27	.36
3/16"	.37	.36	.42
1/4"	.45	.49	.53
5/16"	.67	.69	.93
3/8"	.76	.93	1.1
1/2"	1.05	1.1	1.4
5/8"	2.06	1.9	2.3
1"	2.4	2.3	2.6
Butt Welding			
1/8"	.53	.55	.61
3/16"	.76	.63	.79
1/4"	.87	.73	.93
5/16"	1.05	.93	1.1
3/8"	1.9	1.5	2.3
1/2"	2.06	1.7	2.5
5/8"	3.4	2.8	3.7
1"	3.7	3.4	4.3

Table 2-15 - Flame Cutting Structural Steel (Ref. 10)

WORK ELEMENT DESCRIPTION	MAN-HOURS PER 10 LIN. FT.
1/8"	1.9
3/16"	2.0
1/4"	2.3
5/16"	2.3
3/8"	2.4
7/16"	2.7
1/2"	2.7
5/8"	2.8
3/4"	3.0
7/8"	3.0
1"	4.0
1 1/8"	4.2
1 1/4"	4.4
1 1/2"	4.9
1 3/4"	5.7

Table 2-16 - Rock Drilling and Blasting (Ref. 10)

WORK ELEMENT DESCRIPTION	UNIT	MAN-HOURS PER UNIT
Drill Holes		
Sinker Drill 2 1/2" dia. (Medium)	Lin. Ft.	0.2
Sinker Drill 2 1/2" dia. (Hard)	Lin. Ft.	0.3
Air Trac 2 1/2" dia. (Medium)	20 Lin. Ft.	2.4
Air Trac 2 1/2" dia. (Hard)	20 Lin. Ft.	3.6
Load and Shoot Holes	Each	3.0

## NOTES:

1. Times may vary depending on type of rock, equipment and/or explosives.
2. Figures for blasting are for stick dynamite.

Table 2-17 - Demolition and Removal (Ref. 10)

WORK ELEMENT DESCRIPTION	UNIT	MAN-HOURS PER UNIT
Concrete Foundations	Cu. Yd.	5
Concrete Walls	Cu. Yd.	6
Concrete Slabs on Grade, No Reinforcing	Cu. Yd.	4
Concrete Slabs on Grade, W/Wire Mesh Reinl.	Cu. Yd.	4
Concrete Slabs on Grade, W/Rebar and Mesh Reinl.	Cu. Yd.	6

## NOTES:

1. Work includes removal of item and stacking or piling on site for removal at ground level.
3. For disposal up to five miles, use 1.5 man-hours per cubic yard for rubbish and rubble.
4. Concrete demolition is figured on using pneumatic tools with average crew of two tool operators and three to five laborers.
5. No allowance for salvage of materials (cleaning, pulling nails, etc.) is included in this table.

Table 2-18 - Hand Excavation (Ref. 10)

WORK ELEMENT DESCRIPTION	UNIT	MAN-HOURS PER UNIT
General Excavation of Earth	1 CY	2.7
Trenches to 5' in Earth	1 CY	2.2
Post Holes, Small 3' Deep	1 Lin. Ft.	0.5
Fill Wheelbarrel/Georgia Buggys & Haul	1 CY	1.9
Spread Excess Earth	1 CY	0.9
Trim and Fine Grade	100 S.F.	1.9
Hand Compact W/Pneumatic	1 CY	0.8
Hand Compact W/Vibratory	1 CY	.2

## NOTES:

1. When wheeling over 100' add 25% for each additional 40'.

Table 2-19 - Clamshell (Hourly Production) (Ref. 10)

CLAMSHELL PRODUCTION - 90° SWING LOOSE CUBIC YARD PER HOUR (50 MINUTE HOUR)			
TYPE OF WORK	1/2 CY	1 1/4 CY	2 1/2 CY
Loose Sand/Gravel	40	70	105
PN Excavation	34	60	90

## NOTES:

1. Figures are based on loose cu yds.; use Table 4-19 to find the amount of bank cu yds. (in-place).
2. Boom swing is for 90°.

Table 2-20 - Draglines (Hourly Production) (Ref. 10)

DRAGLINE PRODUCTION - 90° SWING BANK CUBIC YARDS PER HOUR (50 MINUTE HOUR)				
BUCKET SIZE	OPTIMUM DIGGING DEPTHS	CLASS OF MATERIAL		
		SAND/ GRAVEL	COMMON EARTH	DENSE CLAY
1/2 CY	6'	70	58	50
1 1/2 CY	7.4'	116	105	89
2 1/2 CY	8.5'	164	147	127

Table 2-21 - Erosion Control (Ref. 10)

WORK ELEMENT DESCRIPTION	UNIT	MAN-HOURS PER UNIT
Place Jute Mesh, Plastic Netting, or Polypropylene Membrane	1000 S.Y.	4.3
Machine Place RIPRAP- Class "C" Material	1000 C.Y.	96.0
Hand Filling Voids in RIPRAP	1 S.Y.	1.8

Table 2-22 - Rough Carpentry (Ref. 10)

WORK ELEMENT DESCRIPTION	UNIT	MAN-HOURS PER UNIT
Floor Joists, Sills, Girders and Blocking	100 Ft. Bd. Meas.	4
Wall Framing-Studs, Plates and Bracing	100 Ft. Bd. Meas.	4
Ceiling Joists	100 Ft. Bd. Meas.	5
Roof Framing (Pitch Type) and Eave Blocking	100 Ft. Bd. Meas.	6
Roof Framing (Flat Type)	100 Ft. Bd. Meas.	4
Beams (Shaped and Dapped)	100 Ft. Bd. Meas.	13
Beams (Exposed Framing)	100 Ft. Bd. Meas.	10
Trusses, Light (Nailed)	100 Ft. Bd. Meas.	7
Trusses, Heavy (Bolted)	100 Ft. Bd. Meas.	10
Cross Bridging, 2" x 3"	50 Sets or 100 PCS	8
Metal Studs	100 Sq. Ft. of Surface	1
Fabricate and Install Rough Door Bucks (Masonry Walls)	Each Opening	3
Ceiling Stripping	100 Lin. Ft.	3
Furring on Concrete and Masonry Walls	100 Lin. Ft.	3.5
Wood Plaster Grounds on Masonry Walls	100 Lin. Ft.	6
Wood Fences	100 Sq. Ft.	8

## NOTES:

1. Rough carpentry includes the work of measuring, cutting, and installing wood framing, floor joists, sills, cross bridging, wall framing, plates, door bucks, roof framing, and rafters. All work in connection with installing wall and roof sheathing and siding is also included.

Table 2-23 - Placing Concrete (Ref. 10)

WORK ELEMENT DESCRIPTION	MAN-HOURS PER UNIT				
	UNIT	DIRECT FROM CHUTE	WHEELED	PUMPED	CRANE AND BUCKET
PLACE FOOTINGS, FOUNDATIONS					
Grade Beams	Cu Yd	1	2	1.5	1.5
Slabs on Grade	Cu Yd	1.5	3	2	2.5
Walls to 10' High	Cu Yd	—	—	1.68	2.24
Columns	Cu Yd	—	—	1.68	2.24
Suspended Slabs	Cu Yd	—	—	1.68	2.24
Beams and Girders	Cu Yd	—	—	1.68	2.24

Table 2-24 - Mixing Concrete (Ref. 10)

WORK ELEMENT DESCRIPTION	UNIT	MAN-HOURS PER UNIT
HAND MIXING ON SITE		
2 Boards or Boats	Cu Yd	3.2
Machine Mixing On Site (16 S Mixer)	Cu Yd	1.6
Transit Mix Truck	Cu Yd	0.56

## NOTES:

1. Hand mixing tables are based on enough men to keep a smooth constant flow of materials approximately eight men. Man-hour figure (hand) does not include placing; maximum output about 20 Cu Yds. per day.
2. Hand mixing using two boards eliminates waiting for a batch to be mixed before dry charging the mixing board; as the mixer alternate boards. With twelve men the maximum output is about 28 Cu Yds. per day.
3. Warm weather (90 to 100 degrees) will slow mixing time, and add 0.5 man-hours per cu yd.
4. Labor to charge a 16S mixer can be reduced by the use of a small front end loader, but at least one man must remain on each aggregate stock pile to monitor bucket loading.
5. Transit mix man-hours are based on using four trucks, average haul of five miles, and four men operating a dry cement batching plant (Ross or equal).

Table 2-25 - Production Efficiency Guide Chart (Ref. 10)

LOW PRODUCTION			AVERAGE PRODUCTION			HIGH PRODUCTION			
PRODUCTION ELEMENTS (PERCENT)									
	25	35	45	55	65	75	85	95	100
FORESEEN CONDITIONS									
1. Workload	Const. requirement high, misc. overhead high.			Const. requirement normal, misc. overhead normal.			Const. requirement low, misc. overhead low.		
2. Site Area	Cramped working area, no area for material storage, work restricted to design, poor job layout.			Work area limited slightly; partial material storage, some variation from design, average job layout.			Large work area, adequate material storage, wide latitude from design, good job layout.		
3. Labor	Poorly trained, low strength, low morale, high sick call.			Average trained, normal strength; fair morale, normal sick call.			Highly trained, over strength, high morale, low sick call.		
4. Supervision	Poor management, poorly trained personnel, low strength.			Average management, average trained personnel, normal strength.			Efficient management, highly trained personnel, over strength.		
5. Job Conditions	High quality work required, unfavorable site materials, short time operations; insect annoyance high.			Average work required, average site materials, reasonable operation time, insect annoyance normal.			Passable work required, good site materials, long time operation, no insect annoyance.		
6. Weather	Abnormal rain, abnormal heat; abnormal cold.			Moderate rain, moderate heat, moderate cold.			Some rain, occasional heat, occasional cold.		
7. Equipment	Improper job application; equipment in poor condition; repair and maintenance inadequate.			Fair job application, equipment in average condition, repair and maintenance average.			Efficient job application, equipment in good condition, efficient repair and maintenance.		
8. Tactical and Logistical	Slow supply delivery; frequent tactical delays.			Normal supply delivery, occasional tactical delays.			Prompt supply delivery, no tactical delays.		

Annually updated reports titled "Means Construction Cost Data" should be analyzed to determine manpower and cost figures in commercial construction. This may be applied in the area of military construction.

If a specific component is to be replaced or repaired depends not only on time available, but also the convenience of conventional tools and materials at hand. During a hostile assault, repair materials must be identified immediately. Therefore, the materials may not be previously supplied, and make-shift material will have to be found. A good knowledge of the repair assessment and creativity with materials application will assist in optimizing the identification of possible repair materials.<sup>10</sup> This will be discussed in more detail in the repair section of this report.

Equipment and tools needed for a specific task will affect the performance time. The items necessary will be determined by the task at hand and cannot be accurately predetermined.

The weather has a great effect upon construction. Bad weather, such as rain can slow construction operations and sometimes cause additional work, increasing the number of hours of labor required for repair/replace. When divers are required to go into water for demolition or column location and the ocean conditions are not safe enough for a job to be done, all subsequent phases of the project will be delayed.

Figure 2-27 illustrates the decision process for management assessment.

#### **2.4.9 New System Ideas**

The following system can be used in combination with or without previously used assessment techniques. Figure 2-28

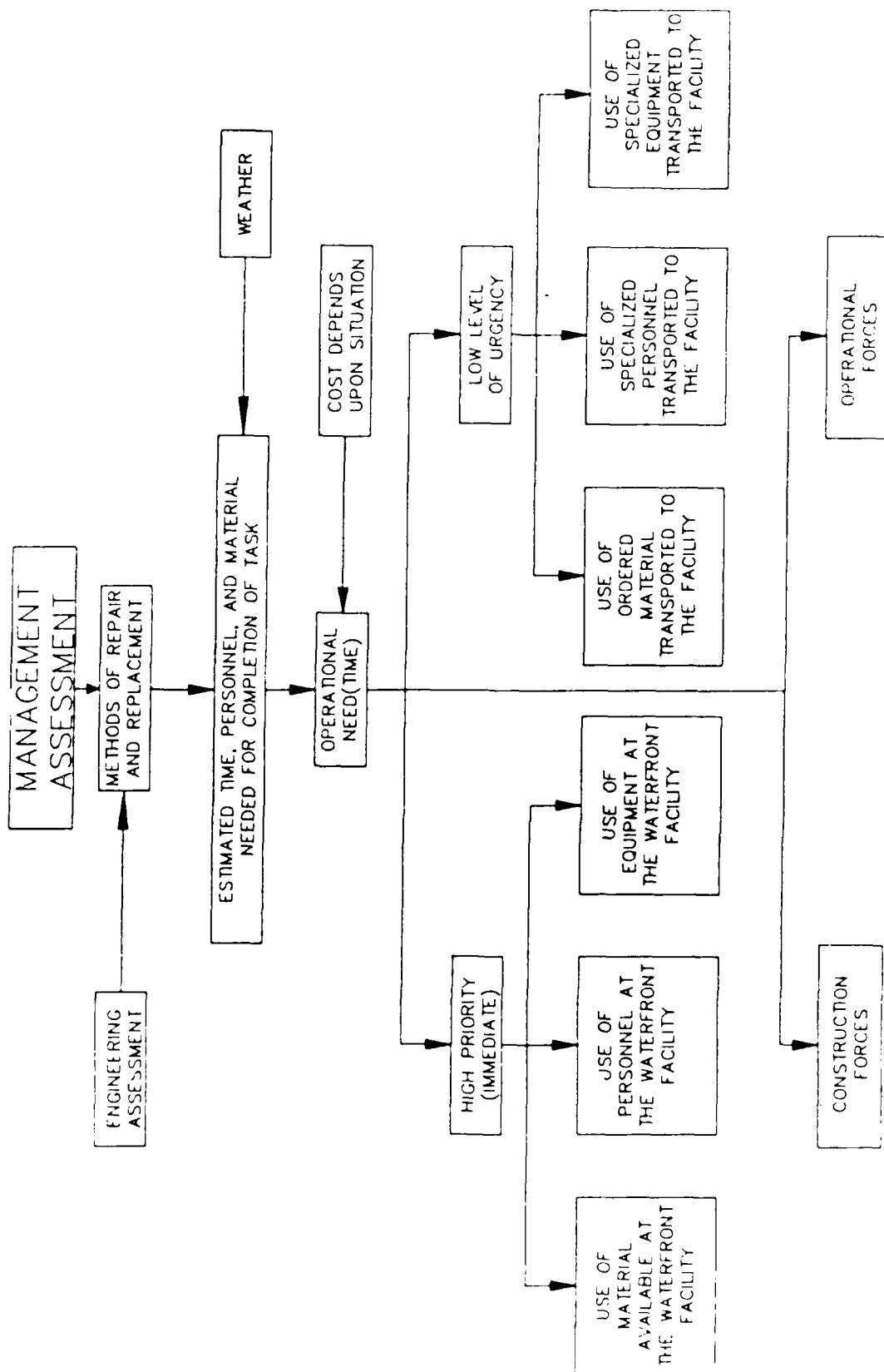


Figure 2-27 - Management Decision Process

DAMAGE FUNCTIONS	MILITARY				ENVIRONMENT									
	ORGANIC DEBRIS	EXPLOSIVES	FACTORIAL FAILURE	ADDITIONAL	COLLISION	EXPLOSIVE	STRESS	COMPRESSION	EXPANSION	TECHNICAL	STRUCTURAL	HAZARD	BOREHOLE	OTHER
1. PERMANENT FILES	ROV & SIDE SCAN SONAR	STRAIN GAUGES	ROV & SIDE SCAN SONAR	ROV & SIDE SCAN SONAR	ROV & SIDE SCAN SONAR	ROV & SIDE SCAN SONAR	ROV & SIDE SCAN SONAR	ROV & SIDE SCAN SONAR	ROV & SIDE SCAN SONAR	ROV & SIDE SCAN SONAR	ROV & SIDE SCAN SONAR	ROV & SIDE SCAN SONAR	ROV & SIDE SCAN SONAR	ROV & SIDE SCAN SONAR
2. UTILITIES														
3. ELECTRICAL														
4. WATER														
5. ROADWAYS														

\* NOTE: THESE SYSTEMS ARE NEWLY INTRODUCED AND CAN BE USED WITH OR IN LIEU OF EXISTING METHODS.



PREVIOUS ASSESSMENT OPERATIONS THAT SERVE WELL



INSUFFICIENT DAMAGE ASSESSMENT TECHNIQUES

Figure 2-28 - Matrix Showing Damage Assessment Operations.\*

illustrates a matrix that defines required waterfront functions/facilities, types of damage and new damage assessment techniques that can be integrated with previous techniques.

#### MINIROVER

The MiniROVER MK II is a remotely operated vehicle (ROV) that functions in shallow to deep water (0 to 1000 Ft.). The vehicle contains a closed-circuit, high-resolution color TV camera. The video picture can be viewed on a surface monitor or a videotape can be examined later. The information is gathered in a manner which gives compass headings of the vehicle, depth from surface, and height from bottom all translated to the video monitor. Two man crew is needed for operation. The weight of the vehicle is approximately 70 pounds. The cost of the vehicle alone purchased from the manufacturer is \$50K. Figure 2-29 illustrates the MiniROVER.<sup>14</sup> Appendix B gives detailed specifications.

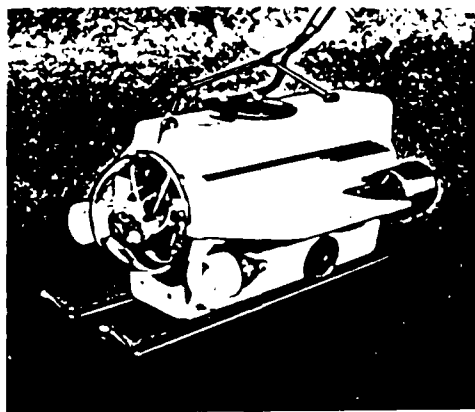


Figure 2-29 - Mini ROVER MK II (Ref. 14).

#### Advantages

1. Operate in adverse conditions.
2. Can operate where divers are liable.

3. Videotape is produced for engineer to examine actual finds.
4. Gives compass headings, depth from surface and bottom of damaged area.
5. Can operate in deep water where divers would have to decompress.
6. System is modular, - ease of mechanical repair.
7. Under favorable conditions, the ROV can inspect a 20' deep square concrete pile in 3 minutes.

#### Disadvantages

1. Visibility less than a foot, visual reception is poor.
2. Water current speeds greater than 1 knot, cannot operate.
3. Must be careful of tangling of tether cord.
4. Must have trained crew to operate.

#### SCANNING SONAR

To increase the efficiency of an underwater damage assessment survey, the use of scanning sonar should be used in combination with ROV's and/or divers. The efficiency of such a system can be achieved in several ways:

- o Additional information for decision making.

- o Obtaining information in a situation which may otherwise be impossible.
- o Safety - use of sonar, rather than divers in a highly dangerous environment.
- o Diver Tracking
- o Cost effectiveness may be achieved by reducing operation time.

With the use of a ROV with T.V. capability, the scanning sonar is most effective. It is unlikely that a superior replacement will ever be found for T.V. in underwater visual inspection, but limitation in range and inability to perform measurements restricts the use of close range visual inspection tasks.<sup>16</sup> Scanning sonar devices can extend the visual range beyond that of a T.V. camera, yet limitations of the information bandwidth make the image forming capabilities fall short of T.V. capabilities. However, there are several marketed high frequency scanning sonars incorporating display features and high resolution which give the operator a presentation more closely identified with T.V. than conventional sonars.

The following is from an article by D. Cattanack and E. W. Cookson which considers the UDI AS360 Scanning Sonar:

Imagine a plan view of an area of the seabed, or a section through the side of a platform, some 200m in diameter. Such an area no side-scan could clearly resolve, nor T.V. camera cover in a single sweep. The AS360 can scan a complete 360° circle around the area (or various segments from 15° to 270°) to provide a real-time T.V.-type picture and video

record.

The AS360's  $27^{\circ}$  vertical by  $1.4^{\circ}$  horizontal beam width, (Figure 2-30), transmitted at 500KHz provides a high resolution video picture. The picture is updated every few seconds such that the movement of submersibles, and even divers and smaller objects, can be clearly detected. It is suitable for both inspections as close as 1m and for much further distances. The sonar range can be varied from 10m to 20m, to 40m and 100m. Close range inspections of structures and trenches can be undertaken with the AS360 in the profile mode and larger areas, as encountered in search applications, up to 200m in diameter can be attempted in the orthodox horizontal scan mode which gives a plan view of the area. But in the latter case the sonar has a far greater resolution than conventional sidescan and gives the operator a presentation more closely akin to that of T.V.

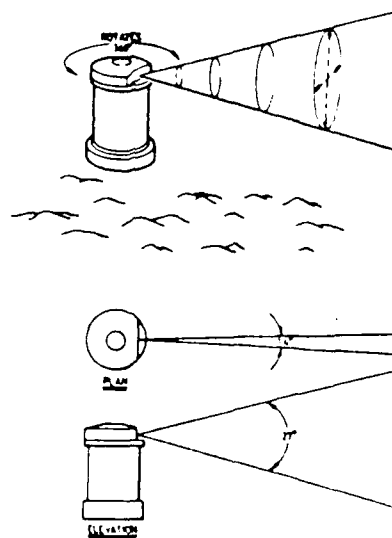


FIGURE 2-30 - AS360 BEAM PATTERN

For waterfront inspection, the scanning sonar can be used in the profile mode to conduct underwater surveys. The sonar is mounted such that it scans vertically through the plane of the pier/wharf to help detect damage to piles and missing braces, also to carry out scour surveys, and to monitor the condition of the waterfront area. The area that is displayed can be 50 meters in diameter of the pier/wharf. This area can not be matched by conventional T.V. inspection. Expensive diving time can be limited to closer inspection of specific areas of the structure. Figure 2-31A and 2-31B illustrates a scanning sonar survey of a North Sea gas platform. The purpose of the survey was to analyze anodes and scour on the structure. The sonar head is positioned in the center of the picture, scanning 360° in a vertical manner.



FIGURE 2-31A - PLATFORM INSPECTION VIDEO.

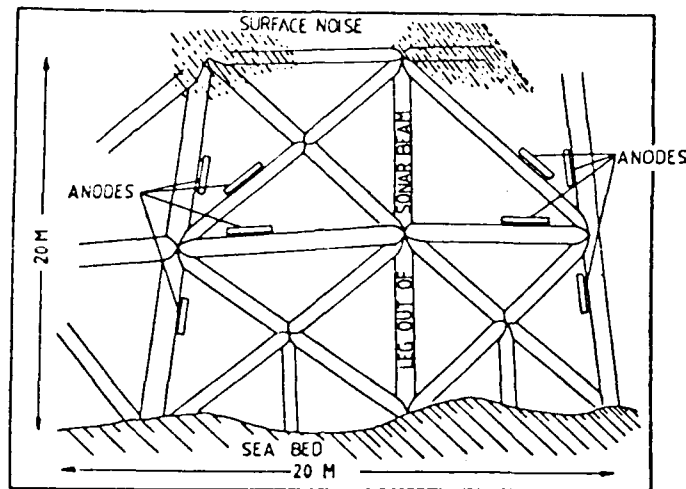


FIGURE 2-31B - PLATFORM INSPECTION SCHEMATIC.

During underwater repair operations, the video format will allow the construction teams essential personnel - engineers, foremans, crane operators - to follow closely, on auxiliary monitors, the underwater operations in real-time while they are actually performing their individual task. In comparison with towed sonar systems, like a sidescan sonar, the sonar record must be time phases due to the relationship of recording with vessel speed. Therefore, a skilled interpretation is needed to judge relative positions and distances accurately, where as, the scanning sonar record does not.

The AS360 head and monitor is shown in Figure 2-32. The scanning head weighs 2Kg in water and can be operated with a conventional pan and tilt mechanism.

The AS360 is extremely versatile in the modes of deployment. The scanning sonar may be attached to a ROV, illustrated in Figure 2-33, or a diving bell, or fitted to a tripod. During the same deployment, both plan and profile views can be obtained.

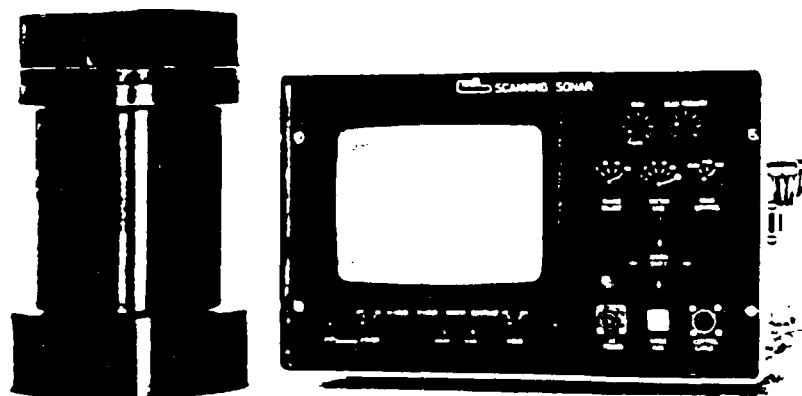


FIGURE 2-32 - AS360 HEAD & MONITOR.

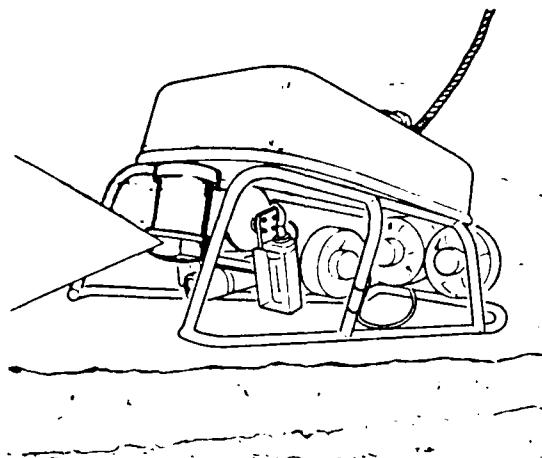


FIGURE 2-33 - AS360 ATTACHED TO ROV.

To date, underwater vehicle designers and operators have often relied entirely upon the maneuverability and versatility of a vehicle to initially locate a target before a close inspection could take place.<sup>17</sup>

During the inspection, divers may be easily tracked by surface crews using scanning sonar. If an underwater communication look is available, the diver can be directed towards targets or away from obstacles. This is important if divers are needed to remove debris over a wide area and where the risk to human life is possible.

Scanning sonar may also be used for harbor surveillance. The AS360 can form either a plan view of the seabed, or a sector through the side of a harbour wall or underwater structure some 200m in diameter. It can scan a complete 360° circle around the area (or various segments from 15° to 270°) to provide a real-time T.V.-type picture and video record. The picture is updated every few seconds such that the movement of submersibles and even divers and smaller targets can be clearly detected.

There are several types of scanning sonars that are available on the commercial market. The AS360 scanning sonar has been discussed due to its ability to be incorporated with ROV's, comparatively low cost, and ease of transportation. Several models of scanning sonars are listed below with approximate price. Detailed descriptions are found in the Appendix C of this report.

<u>MODEL 3</u>	<u>APPROXIMATE COST</u>
AS360 MS5	\$22K w/o monitor
AS360 MS1A	\$30K w/o monitor
AS370	\$225K
AS380	\$425K

## SIDE SCAN SONAR

When environmental factors eliminate the use of ROV's or the area is too large for scanning sonar and the large area must be covered quickly, acoustical imaging in the form of side scan sonar can provide a great deal of information. The high resolution side scan sonar can provide an excellent overview of damaged areas. Its ability to rapidly produce photograph-like images of seafloor topography have made its application towards waterfront assessment increasingly popular.

To understand how side scanning is used lies in the nature of the sonar recording process. Figure 2-34 illustrates the side scan sonar and the side scan sonar technique. The following is from Reference 18:

The transducer is a linear array which transmits a beam that is broad in one direction and very narrow in the other. In normal usage a pair of transducers are mounted in a towed body such that the broad beam is vertical and the narrow beam is horizontal. The transducer body, or towfish, is pulled through the water by an electro-mechanical cable, which carries the power and signals to and from the graphic recorder on board the vessel. As the tow body moves along, successive pulses produce echoes from strips of the sea floor. The broad vertical beam provides coverage from directly beneath the transducer out to the full range selected by the operator. The transducers are towed at some height above the sea floor, so the distances to bottom features are slant ranges and not a true scale presentation. The individual pulses are laid down side by side by the graphic recorder to form a detailed image of the seafloor.

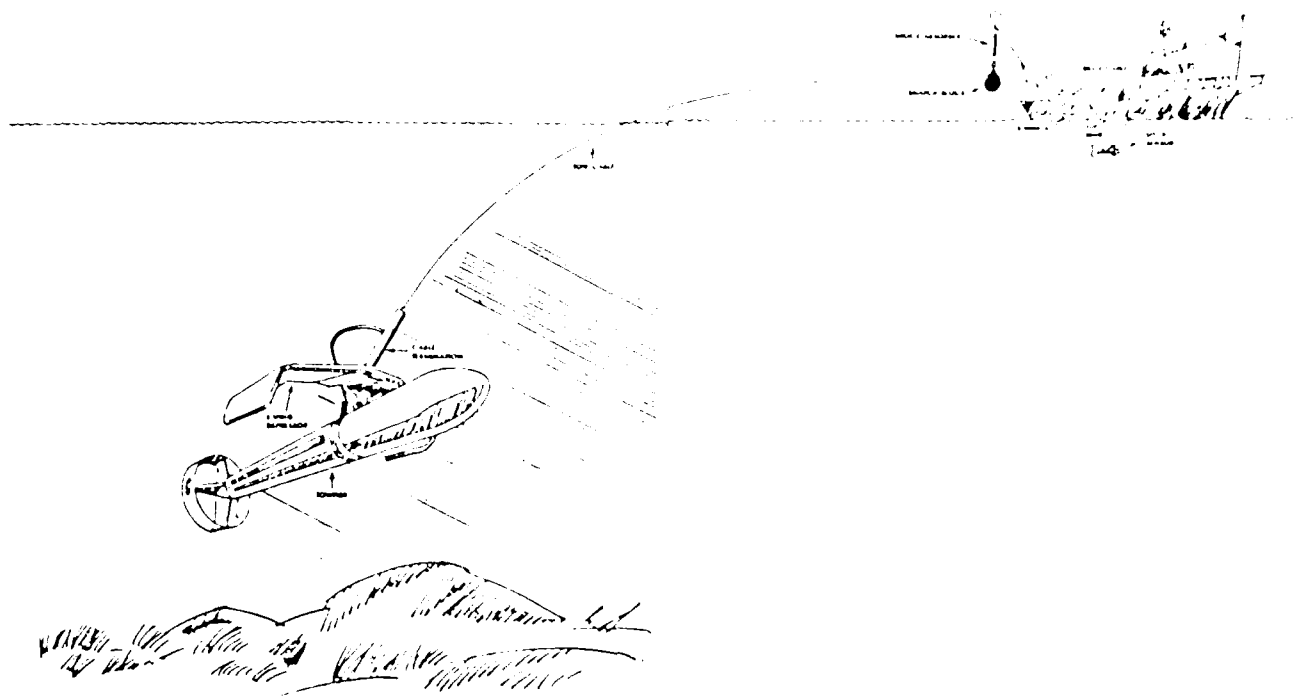


FIGURE 2-34 - SIDE SCAN SONAR

The resolution that is achieved from side scan sonars have made it a viable technique for waterfront facility inspection. Though primarily used for large areas, the side scan sonar can detect some fine detail but will not discern the degree of deterioration of a single piling. Figure 2-35, courtesy of Klein Associates, Inc., shows a 500 KHz record of pier pilings in Norfolk, VA showing broken and damaged piles. Note the clarity and detail of the high resolution recording.

Another inspection using side scan sonar was conducted by Hydromar, Ltd., of Trois Rivières, Quebec, Canada in Quebec Harbor. The survey was conducted on a pier face. For further details on the inspection, the reader is referred to the paper by Mazell<sup>18</sup> and the report by Hydromar, Ltd. <sup>19</sup>

A sample side scan sonar record obtained by Hydromar is shown in Figure 2-36. This shows a front view of the pier. The following is a description of the findings by Mazell<sup>18</sup>:

The image shows the texture of the concrete and any discontinuities in the surface. The horizontal lines parallel to the top and bottom of the pier are the small (1 cm) cracks left in the pier face by the form used for pouring the concrete. At the right side of the record is an area where the pier construction has changed to wood, made up of square-cut beams laid horizontally. The record is light in the area of the wood because it is smoother than the concrete and returns less sound to the sonar. With proper tuning the tiny cracks between the beams could be seen, along with any deformations on the surface.

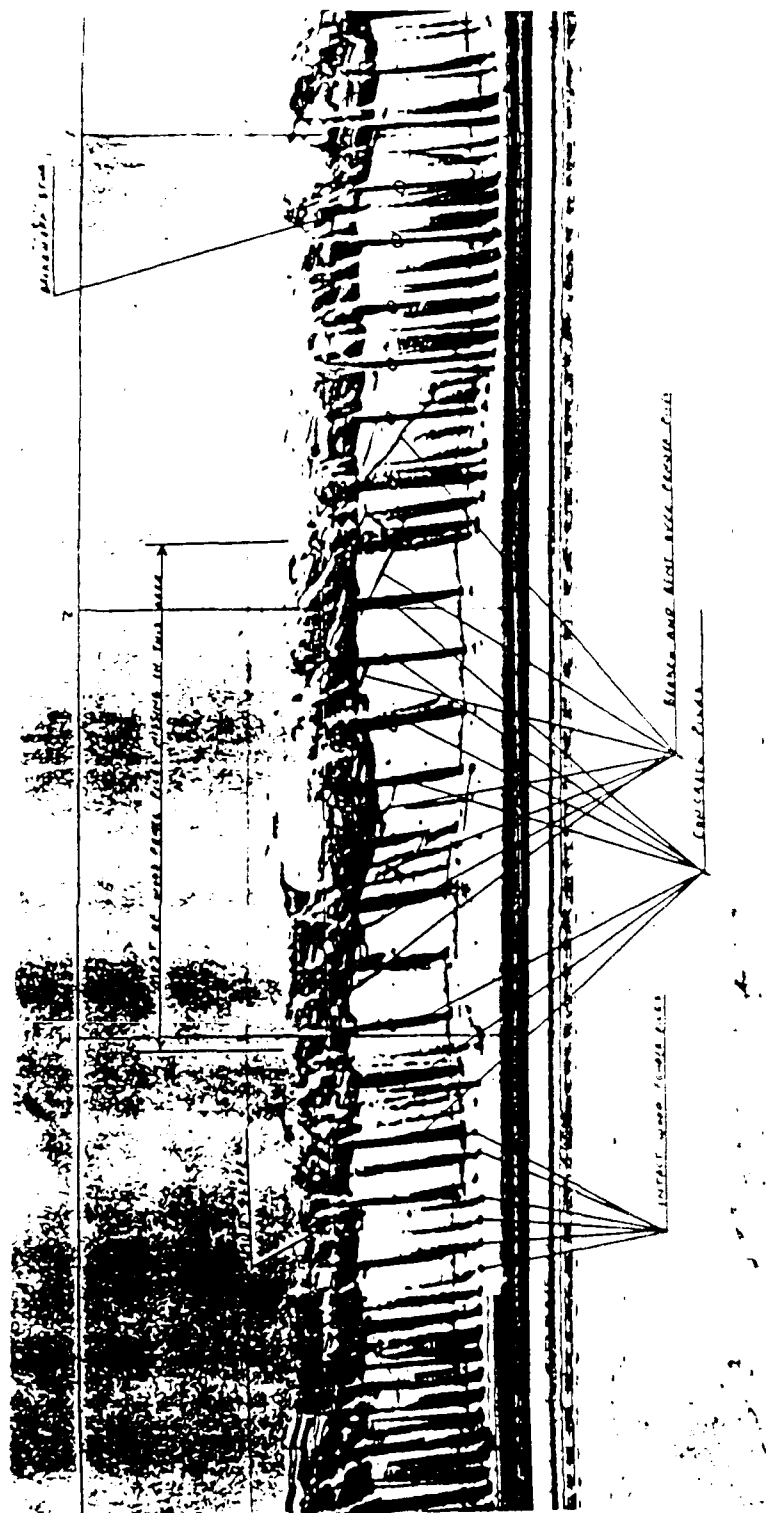


FIGURE 2-35 RECORD OF PIER PILING

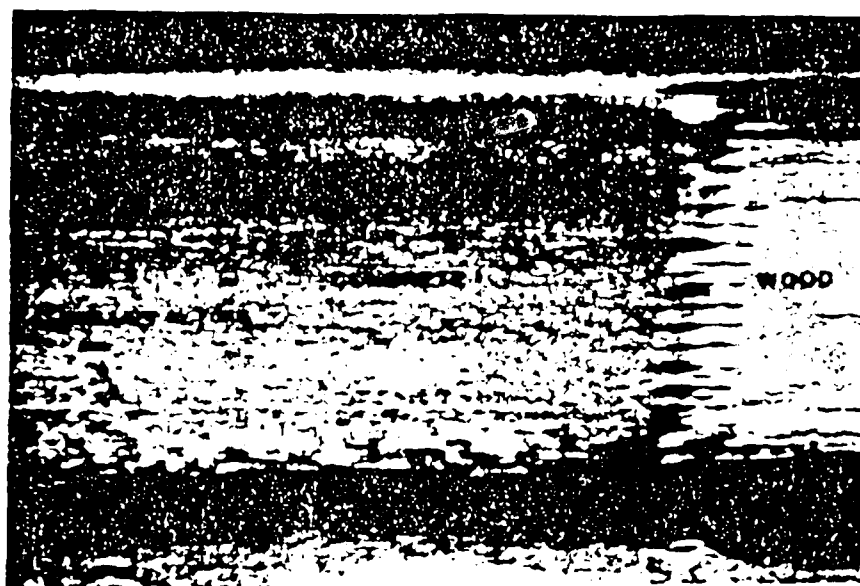


FIGURE 2-36 - SIDE SCAN SONAR RECORD OF PIER FACE, QUEBEC, CANADA

The side scan sonar system offers an advantage in underwater assessment is the speed at which a large area can be inspected. The results are immediately available through the direct recording process. This makes interpretation of the situation immediate. The hardware is available off the shelf and is readily adaptable to a wide range of survey platforms. Specifications of the system are found in Appendix D. The following are approximate prices for the Model 590 side scan sonar system components offered by Klein Associates, Inc.

<u>Item</u>	<u>Approximate Cost</u>
Model 595 Recorder - When Configured To Accept:	
- 100 kHz/500 kHz Dual Frequency Side Scan and 3.5 kHz Profiler Data	\$41,325.00

<u>Item(cont.)</u>	<u>Approximate Cost</u>
- 100 kHz/500 kHz Dual Frequency Side Scan	\$39,203.00
- 100 kHz or 500 kHz and 3.5 kHz Dual Frequency	\$35,490.00
- 100 kHz or 500 kHz Single Frequency	\$33,368.00
Model 422S-101HF Dual Frequency Towfish	\$22,500.00
100 Meter Multi-Channel Lightweight Tow Cable. (Longer lengths available at \$15.93 per additional meter.)	\$ 2,993.00
100 Meter Multi-Channel Armored Tow Cable (Longer lengths available at \$13.98 per additional meter.)	\$ 2,698.00*
*Armored Cable Cut and Reel Charge, per length	\$ 175.00

#### STRAIN GAUGES

A strain gauge is a device employed to measure change in length over a gauge length or to detect strain at a point. Electrical strain gauges of many types have become popular in recent years because of their light weight, small size, ability to work in dynamic conditions, remote sensing and recording possibilities, relatively low cost, and other important advantages including extreme strain sensitivity. Construction of a typical bonded resistance gauge is shown in Figure 2-37.

To use the electrical resistance gauge, the gauge is first bonded to the material under going strain so that it essentially becomes a part of the material to be loaded with deforms with the material. The wires or foil of the gauge filament will then be strained producing an electrical effect.

The use of the strain gauge may be incorporated during construction of the facility. The gauges are then connected to a computer so that at any time the strain on the decking or pile may be determined. This is useful to determine overloading or to be used during the engineering assessment.

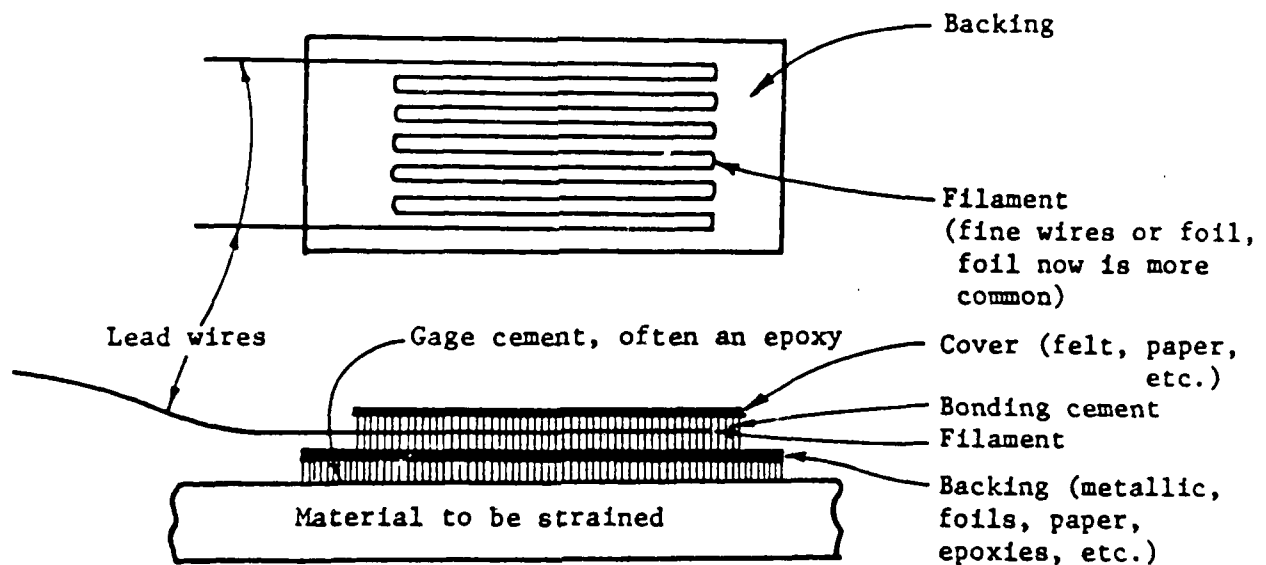


Figure 2-37 - Electrical Resistance Wire Strain Gauge (Ref. 15).

#### 2.4.10 New Requirements for Inspection

Requirements for inspection refer to post military attack as well as to a inspection performed during peacetime environment. The following criteria is followed by Naval Operations for the condition and safety of bridges.

- o Structure is inspected underwater at intervals of once a year, with 15 months being the longest period. Structures which are especially critical or susceptible to deterioration are placed on shorter intervals.
- o Newly constructed structures, and repairs to structures, are inspected during and at the end of the construction, insuring proper construction techniques.
- o One hundred percent of all underwater elements are visually inspected, ten percent are cleaned and probed and five percent are measured or tested.
- o Underwater color photographs are used no matter how poor the water conditions.
- o Each facility is analyzed for load carrying capacity temporary restrictions are ordered if necessary.
- o Inspection engineers should have diving qual.

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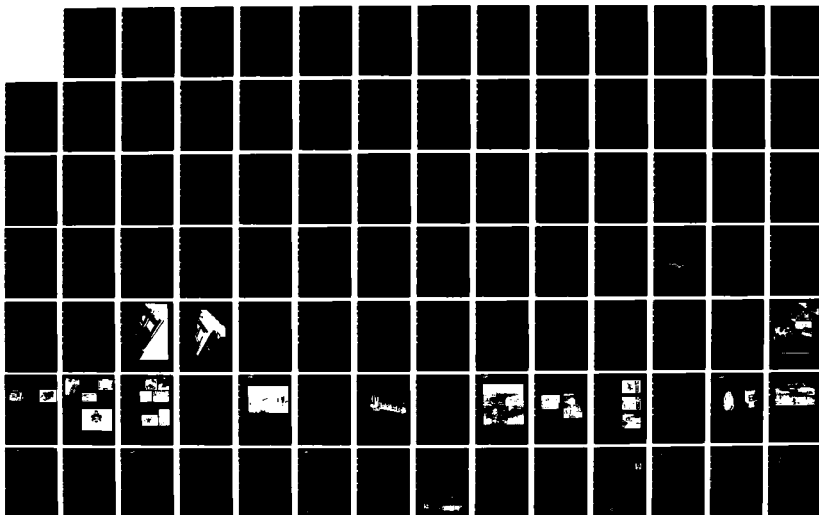
WATERFRONT DAMAGE REPAIR FOR AMPHIBIOUS AND ADVANCED  
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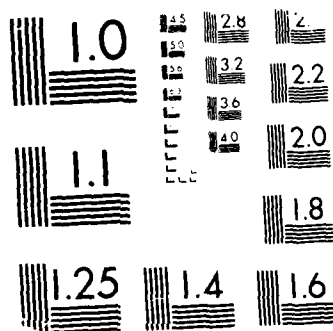
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## 2.5 REPAIR

The repair process to be used is derived from the engineering and management assessment of the total situation. The engineering assessment develops the safety condition, capacity of the structure, and the extent/deterioration rate of the structure. From these three main findings, several repair methods are generated. To determine the most effective repair, a management assessment is performed. This analysis compares repair method criteria to that of the "needs" of the waterfront facility (e.g., time, available material, personnel, etc...). To determine if a repair is applicable, these characteristics should be adhered to:

- o Attainable material.
- o Assembly should be as simple and accomplished with as many non-specialized personnel and tools as possible.
- o Minimum preparation time for repair.
- o Assembly should be of few differing components.
- o Repair should be stronger than the system replaced to account for permanent structural damage to surrounding areas.
- o Must accommodate maximum expected container loads(30 Long tons), tanks(60 LT), etc...

The following methods of repair will be discussed in three sections: foundations, piles, and decking.

### **2.5.1 Repair Methods For Foundations (Existing Concepts)**

Piles are used to transmit the load to a deep stratum that is strong enough to bear the loads or to develop sufficient friction around the surface of the piles. If expedient repair is necessary to replace a pile where the original base of the pile cannot be used, or if there is need for a pile where previously there was none, an expedient foundation may be used. The foundation is a prefabricated base, composed of attainable material around the facility. The theory behind a foundation is to distribute the load from the pile over a wide area. The actual design is dependent upon type of soil, load, and physical properties of the materials.

Several foundation designs will be discussed.

- o Steel beam foundation
- o Concrete foundation
- o Rubble foundation
- o New conceptual designs

#### **2.5.1.1 Steel Beam Foundation<sup>10</sup>**

Figure 2-38 illustrates the steel beam foundation. This design uses butt welded wide-flange beams to distribute the pile loads over a wide area. The area must be level and cleared of debris for total load transference to the soil. Table 2-26 provides planning and estimating data for steel beam foundation.

#### **2.5.1.2 Concrete Foundation<sup>10</sup>**

Figure 2-39 illustrates the expedient concrete foundation.

This design uses halved 55-gallon drums filled with mesh reinforced concrete. The large surface area of the concrete transmits the load of the pile to the soil. Threaded rod is embedded in the concrete to anchor wide flange beams to the drums to provide a means for attaching the pile to the foundation. Like the steel beam concept, the area must be level and cleared of debris for total load transference to the soil. Table 2-27 provides planning and estimating time for concrete foundation.

#### **2.5.1.3 Rubble Foundation<sup>10</sup>**

The concept of a Rubble foundation is illustrated in Figure 2-40. Like the steel plate foundation, rubble and early high strength concrete provide a foundation for a pier pile. The sea floor is excavated by the use of air jet or air lift. Rubble is placed into the cavity. The repair pile is lowered by variable buoyancy air bags into the cavity, then concrete is pumped into the remaining volume of the excavated area. The pile is then braced to adjacent piles. Table 2-28 provides planning and estimating time for rubble foundation.

#### **2.5.1.4 New Conceptual Designs For Foundation**

The following two designs are conceptual in-nature and require further evaluation.

##### **2.5.1.4.1 Steel Plate Foundation**

The steel plate foundation is illustrated in Figure 2-41. A water jet or air lift is used to excavate around the base of the pile. The failed pile is cut to the bottom of the excavated area. Rubble is lowered and placed in the hole about half-way to add support. Early high strength concrete is pumped into the hole to fill the original grade of the sea bottom. High strength galvanized bolts are set into the concrete. After concrete has

time to set up, wide flange beam with a welded steel plate is lowered by variable buoyancy lift bags. The beam is set into place and bolted. Shims are used to fill gap between pile caps and pile. Table 2-29 provides planning and estimating time for steel plate foundation.

#### **2.5.1.4.2 Skirt Foundation**

This type of design for a foundation has been used on a larger scale with concrete gravity structures in the North Sea oilfields. The design operation is to transmit axial and bending moments to the large, heavy foundation which counteract these forces.

The skirt foundation shown in Figure 2-42 is shown on a smaller scale. This foundation is precast, and therefore can be immediately used. The skirt would be airlifted to the site, wherein a pile would be inserted into the pile couple and fixed to the pile cap with shims.

### **2.5.2 PILES**

As discussed in a previous section, there are many causes for why piles will deteriorate in the marine environment. The following methods for the repair of steel/concrete/timber piles were developed by Reference 3. New concepts will be introduced at the end of the section.

#### **2.5.2.1 Steel Piles (Existing Concepts)**

There are several methods for the repair of steel piles. These methods are grouped into five categories: concrete encasement partial replacement, complete replacement, coating/wrapping, and cathodic protection.

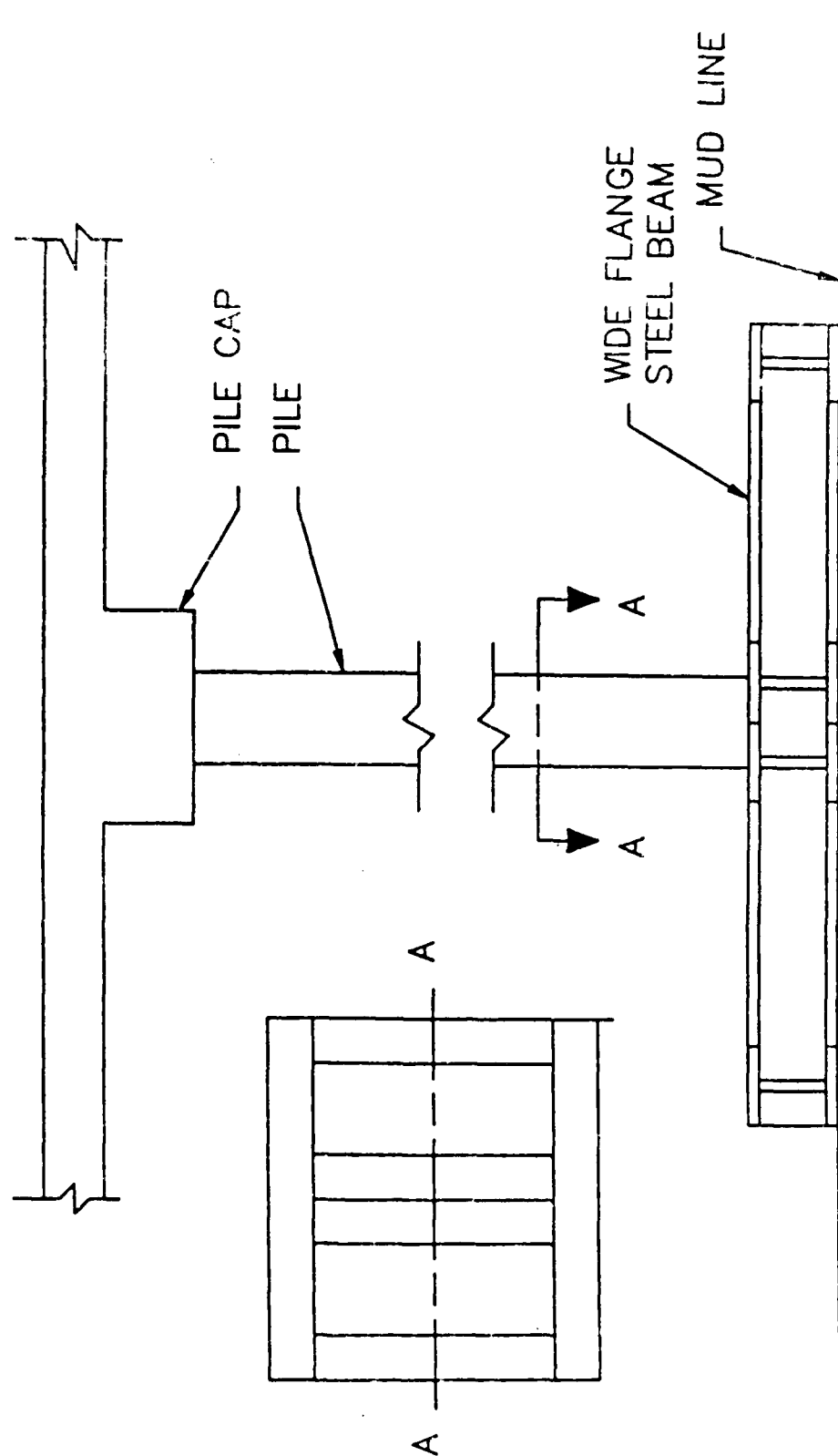


Figure 2-38 - Steel Beam Foundation.

Table 2-26. Planning and Estimating Data for  
Steel Beam Foundation

Description of Task: Repair a deteriorated portion of a driven pile with a prefabricated expedient foundation at the mud line. The foundation will be 10' x 10' using wide flange beams to support a 2' diameter steel pile.

Size of Crew: 2 divers, 1 welder, 1 steel worker, 1 laborer.

Special Training Requirements: Familiarity with above-water welding, underwater lifting procedures.

Productivity of Crew: 0.56 hours per inch of frame perimeter.  
(56 hours for 10' x 10' frame.)

Equipment: Arc cutting torch equipment, crane or lifting equipment, oxy-acetylene torch, variable buoyancy lift bags.

Materials: The area and beam size depends upon the load that the facility carries. The type of beam used would be wide flange beams. Yield stress of steel will also be load dependent.

Potential Problems: The area must be level and cleared of all debris. Settling may occur causing the foundation not to carry the load. The foundation frames must be floated into position by variable buoyancy lift bags.

Table 2-26 - Planning and Estimating Data for Steel Beam Foundation.

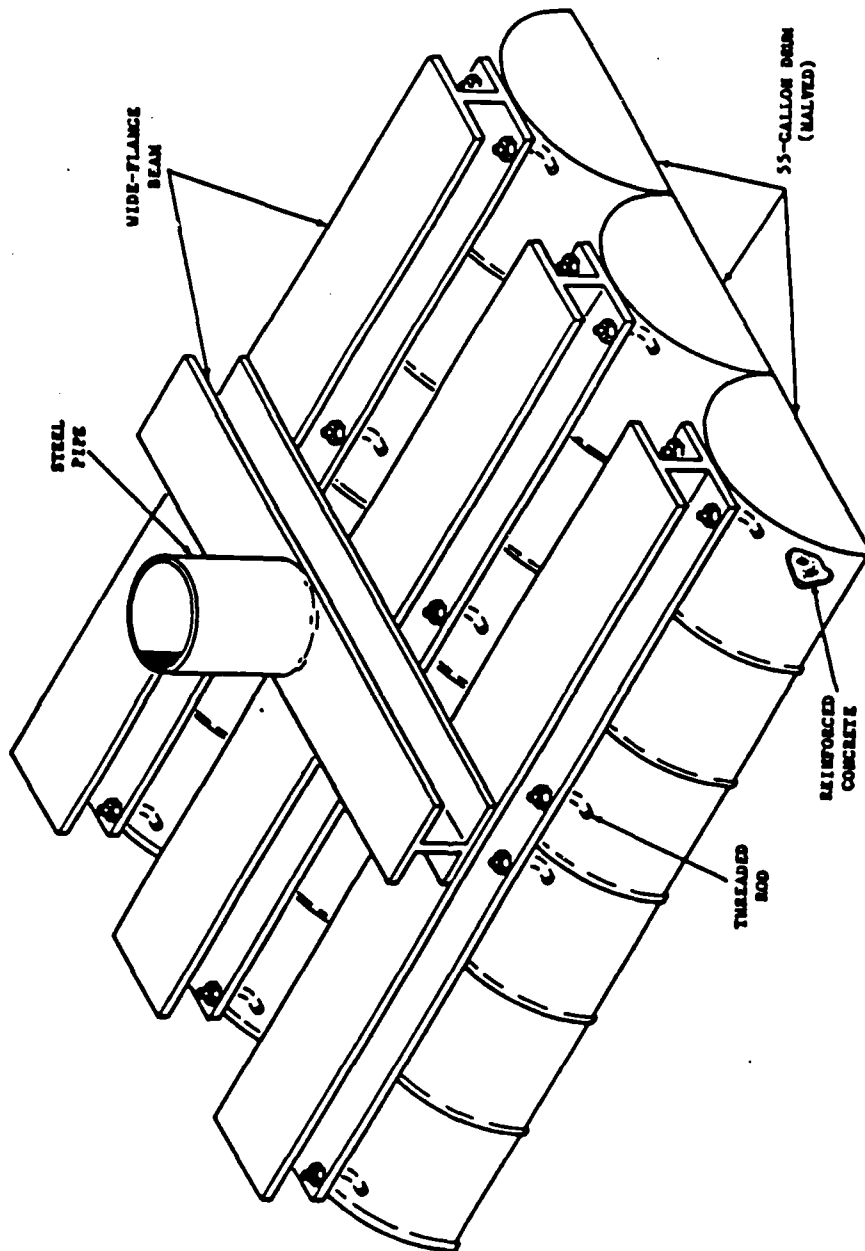


Figure 2-39 - Expedient Concrete Foundation (Ref. 10).

Table 2-27. Planning and Estimating Data  
for Concrete Foundation

Description of Task: Repair a deteriorated driven pile by replacing with a concrete foundation at the mud line. Concrete foundation consisting of 55 gallon steel drums and wide-flange steel beams.

Size of Crew: 2 divers, 1 welder, 1 steelworker, 1 laborer

Special Training: Familiarity with procedures for concrete pouring, framework fabrication and installation, above water welding, underwater lifting procedures.

Equipment: Oxygen arc cutting torch equipment, crane or lifting equipment, oxy-acetylene torch equipment, hydraulic power unit, hydraulic drill with bits, variable buoyancy lift bags.

Productivity of Crew: 65 hours for fabrication and placement for 3-55 drums filled with concrete, 4-9' W 12 x 72 beams welded.

Materials:

The area and beam size depends upon the load that the facility carries. The type of beam used would be wide flange steel beams.

Concrete

Concrete used is  $F_c' = 3$  ksi. To determine amount of concrete required depends upon the area of the form. Wire mesh is used for reinforcement.

Fittings

Threaded bolts are bent. The size required depends upon size of wide flange beams.

Potential Problems: The area must be level and cleared of all debris. Settling may occur causing the foundation not to carry the load. The foundation frame must be floated into position by variable buoyancy lift bags.

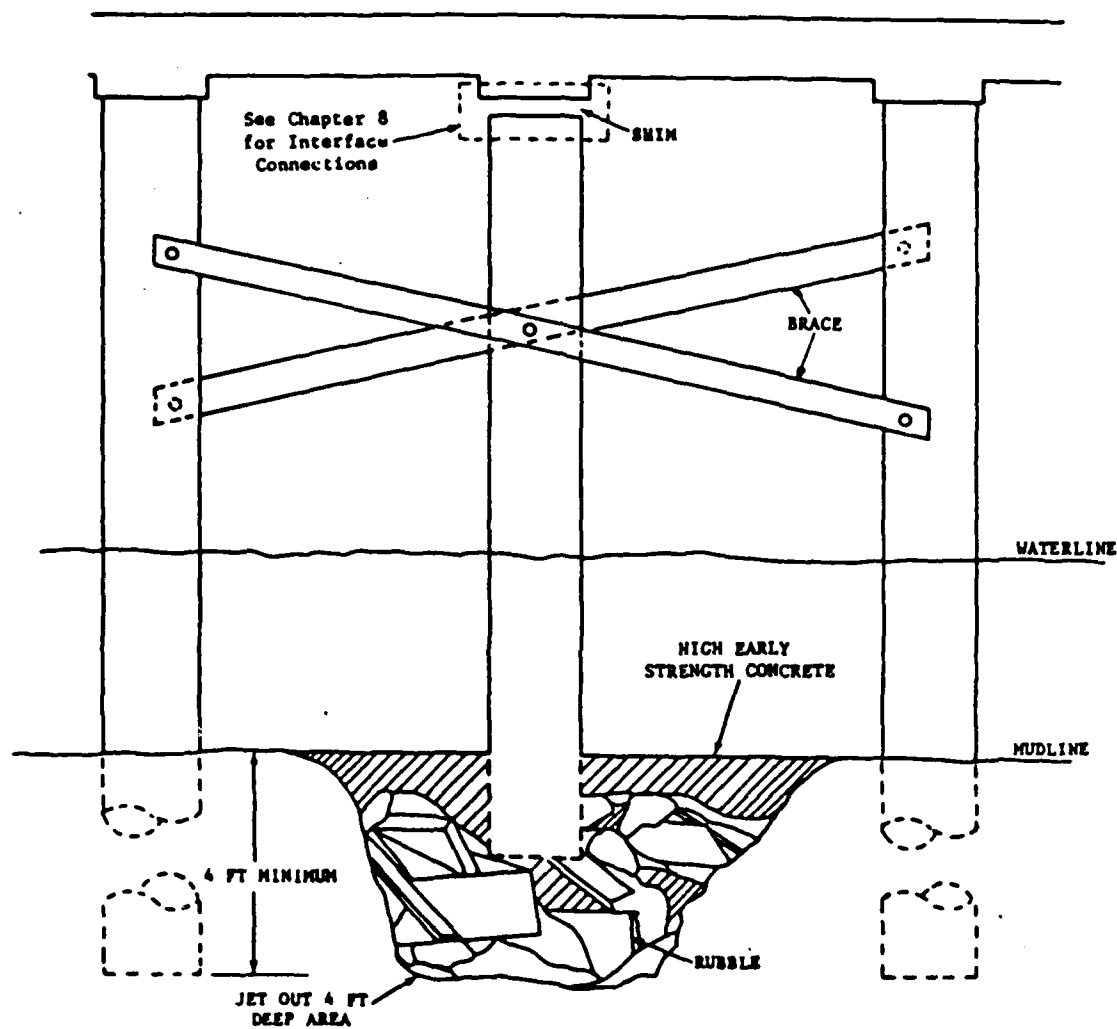


Figure 2-40 - Rubble Foundation (Ref. 10).

Table 2-28. Planning and Estimating for  
Rubble Foundation

Description of Task: Repair a deteriorated portion of a driven pile by constructing a concrete/rubble foundation. Added support comes from the use of a brace. The foundation of the original pile is excavated and replaced with rubble and early high strength concrete. Metal brace is used for lateral stability. Top of column is fitted to pile cap using shims.

Size of Crew: 2 divers, 1 crane operator, 1 laborer

Special Training Requirements: Familiarity with underwater excavation techniques, crane operation, underwater lifting procedures.

Equipment Requirements: Airlift, crane or lifting equipment, variable buoyancy lift bags, concrete pumping equipment, hydraulic drill and bits.

Productivity of Crew: 17 hours per pile

Materials:

The pile size depends upon the load that will be carried. Brace depends upon distance from adjacent piles.

Concrete

Concrete used is  $F_c' = 3$  ksi. The amount of concrete required depends upon the excavated volume.

Potential Problems: Excavation may be prolonged depending upon soil composition.

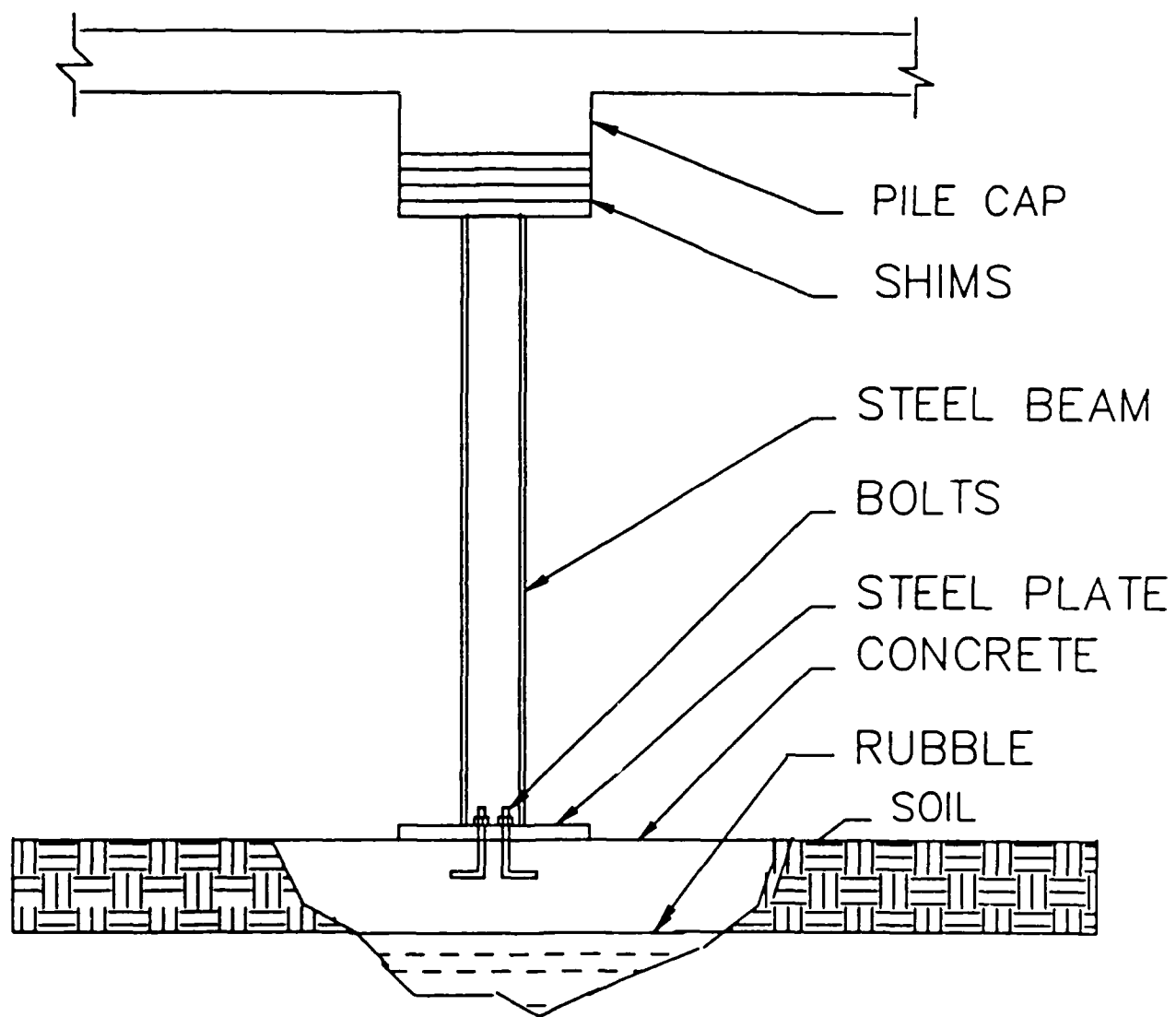


Figure 2-41 - Steel Plate Foundation

Table 2-29. Planning and Estimating Data for  
Steel Plate Foundation

Description of Task: Repair a deteriorated portion of a driven pile by constructing a steel plate foundation. The foundation of the original pile is excavated and replaced with rubble and early high strength concrete. High strength bolts are set into concrete. Wide flange beam with welded base plate is bolted to footing. Top of beam is fitted to pile cap using shims.

Size of Crew: 2 divers, 1 welder, 1 crane operator, 1 laborer

Special Training Requirements: Familiarity with above-water welding, underwater excavation techniques, crane operation, underwater lifting procedures, drill and bits

Equipment Requirements: Airlift, arc welder, crane or lifting equipment. Variable buoyancy lift bags, concrete pumping equipment.

Productivity of Crew: 20 hours per pile

Materials:

The beam size, plate size and bolts depends upon the load that the column will carry.

Concrete

Concrete used in  $F_c' = 3$  ksi. The amount of concrete required depends upon the excavated volume.

Potential Problems: Excavation may be prolonged depending upon soil composition.

#### **2.5.2.1.1 Concrete Encasement**

Concrete encasement is a common repair technique used for semi-deteriorated piles. This adds strength to the pile against buckling and axial forces. In the splash zone, concrete encasement is used for corrosion and abrasion protection. The two types of encasement are flexible and rigid form. Each encasement technique involves the cleaning of the pile of marine growth and loose rust using high pressure waterblaster.

#### **2.5.2.1.2 Flexible Forms**

A flexible form (Figure 2-43) incorporates the use of a 6x6-inch wire reinforcing mesh to be placed around the pile, using 3-inch PVC spacers to hold the mesh away from the pile. A fabric form is placed around the pile, and secured by the use of mechanical fasteners top and bottom. Concrete is then pumped into the fabric form through seacocks using a hose that extends to the lowest point of the form. To avoid creating voids, the form should be vibrated. When the form is completely full, the seacocks should be closed and the pump hose removed.

#### **2.5.2.1.3 Rigid Forms**

A rigid form (Figure 2-44) uses a fiberglass form rather than a fabric form. This type of form incorporates a temporary wood base plate (Figure 2-45) and friction clamp assembly. Wire reinforcing mesh is attached to spaces to insure 1-1/2 inches of concrete cover. The fiberglass reinforced polyester jacket is installed around the pile and locked with a Z-bead closure. Concrete is pumped until it begins flowing from the top, wherein a 45-degree angled epoxy cap is attached to the top of the form.

In some cases, a fiberboard may be used rather than the fiberglass system (Figure 2-46). This incorporates split

fiberboard and the same system of reinforcement as the fiberglass system except for the use of straps for support rather than reinforcing bands.

Concrete encasement is a technique that can be used for the prevention of corrosion and abrasion. This can be installed during the construction phase or after construction.

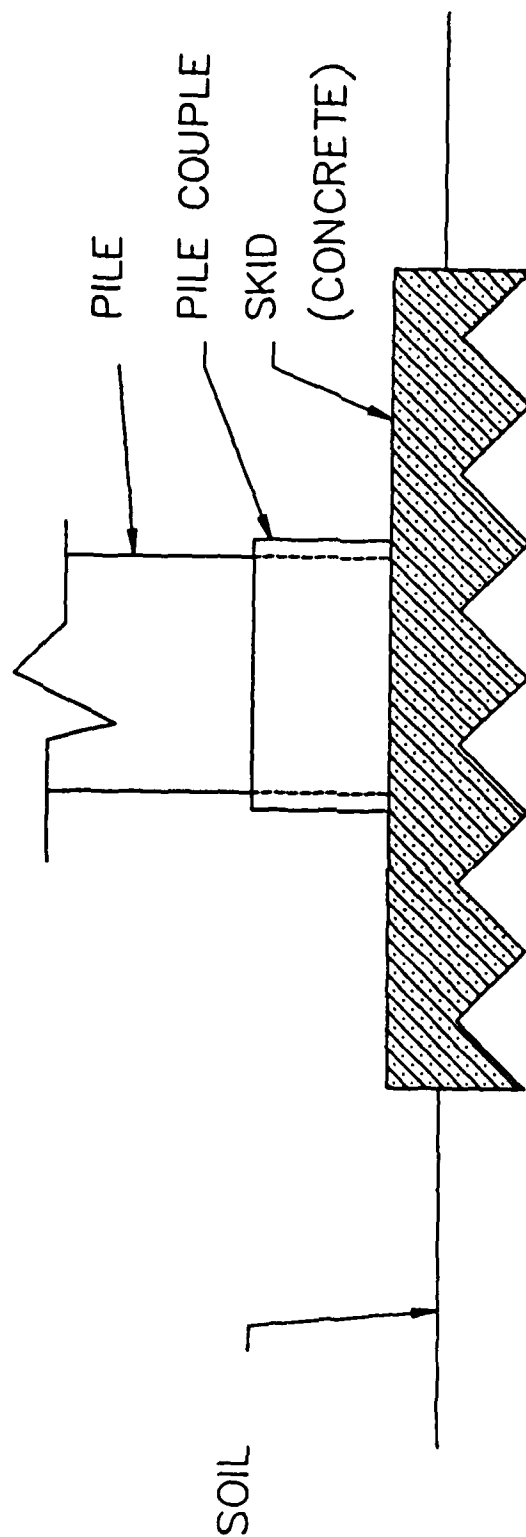


Figure 2-42 - Skirt Foundation

Table 2-30 provides planning and estimating data for repair of steel piles using concrete encasement.<sup>3</sup>

#### **2.5.2.1.4 Partial Replacement**

Corroded sections of H-piles can also be repaired by replacing with a new piece of H-pile as illustrated in Figure 2-47. The corroded section of pile is cut out being sure that the bottom and top cuts are square. Temporary supports may have to be provided to transfer the load from the pile being repaired to adjacent piles. A welded assembly of a 1-inch steel bearing plate, two 3/8-inch steel side plates, and four steel angles is fabricated above water and placed over the bottom cut. Holes are drilled or burned through the H-pile flange and web, using the predrilled holes in the assembly as a template. The assembly is bolted together with 1-1/4-inch galvanized steel bolts. A section of new H-pile is then cut to fit the missing length of pile and a 1-inch steel bottom bearing plate is welded to the new section. The replacement section is placed into position and the bearing plates are bolted together. The upper joint and four 5/8-inch steel splice plates are welded to both H-pile sections.

A similar method, illustrated in Figure 2-48, involves a direct attachment of the new pile post to the pier deck using a 1-inch bearing plate bolted to the deck. This arrangement is necessary when the steel has corroded extensively at the concrete-steel interface.

Table 2-31 provides planning and estimating data for repair of steel piles using partial replacement.

#### **2.5.2.1.5 Complete Replacement**

In some cases, it is more economical to replace rather than repair. There are several methods for expedient replacement. One such method that corresponds to concrete decking, consists of

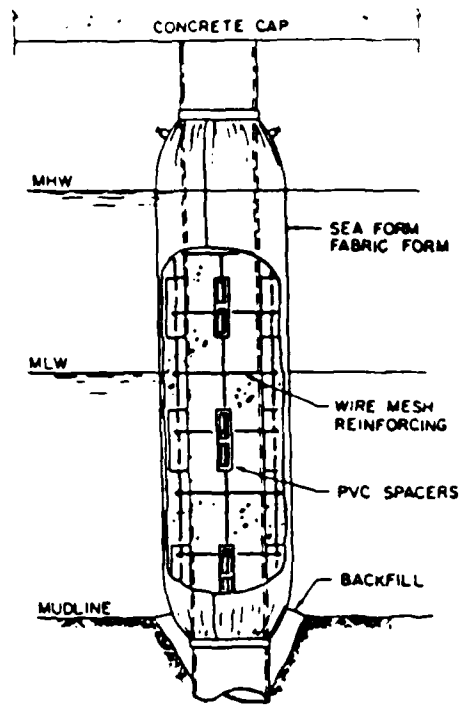


Figure 2-43 - Flexible Form Concrete Encasement Repair of Steel Pile (Ref. 3).

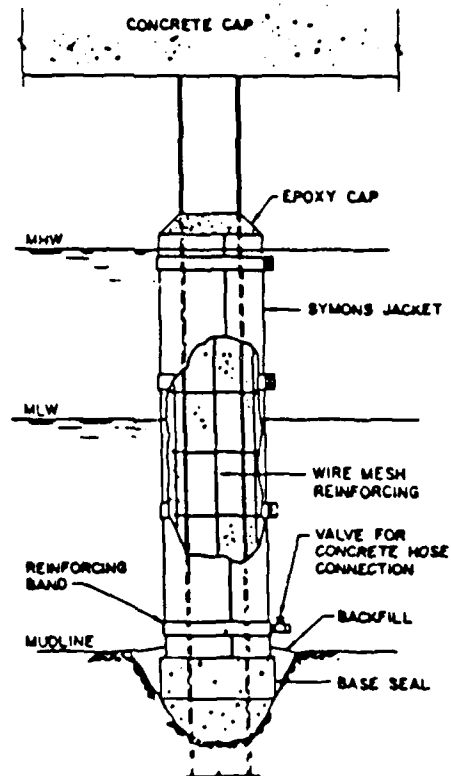


Figure 2-44 - Fiberglass Rigid Form Concrete Encasement of Steel Pile (Ref. 3)

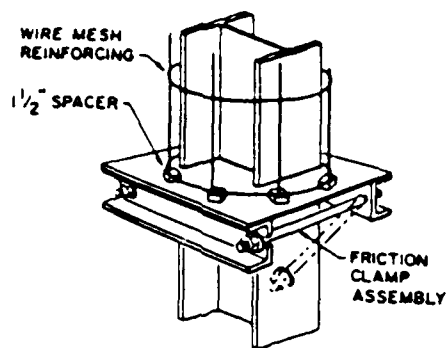


Figure 2-45 - Rigid Form Base Plate and Friction Clamp Assembly (Ref. 3).

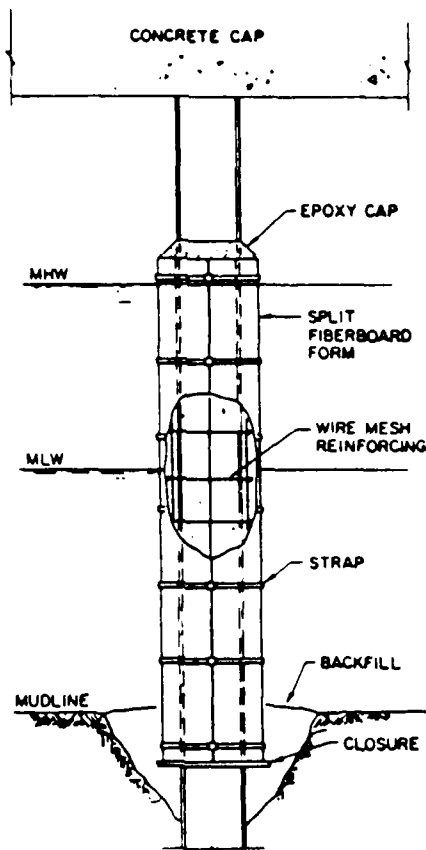


Figure 2-46 - Fiberboard Rigid Form Concrete Encasement of Steel Pile (Ref. 3).

Table 2-30 - Planning and Estimating Data for Steel  
Pile Repair Using Concrete Encasement (Ref. 3)

Description of Task: Repair a deteriorated steel pile by installing a concrete encasement from 1 foot above the high water line to 2 feet below the mud line. The total length of encasement is 20 to 30 feet. Reinforcement of the pile is not required.

Size of Crew: 2 divers, 2 laborers.

Special Training Requirements: Familiarity with the type of jacket to be used for the concrete form, concrete pump operation, jetting or air lifting procedures, and removal of marine growth.

Equipment Requirements: High-pressure waterblaster, hydraulic grinder with Barnacle Buster attachment, hydraulic power unit, concrete pump with adequate hose, concrete slump cone, air jetting pump and hose, rigging equipment, float stage, scaffolding. If ready-mix concrete is not available, provide a concrete mixer and other equipment (e.g., wheelbarrows, shovels, etc.) as needed.

Productivity of Crew: 6 hours per pile repair.

Materials:

Form Material

Either flexible or rigid forms may be used. When using proprietary forms, follow manufacturers' recommendations regarding lengths and diameter of forms, top and bottom closures, spacers, bands, straps, and special fittings. Forms are ordered prefabricated in the required length and diameter. For flexible forms, allowance on the length must be made for extra fabric that may be required around blocking at the top and bottom of the jacket. Some proprietary systems require that different types of forms be used in the tidal and submerged zones.

Spacers

A conservative estimate of the number of spacers must be made. In calm water and with vertical piles, relatively few spacers will be required. Rough water and batter piles will require more spacers.

Wire Mesh Reinforcing

Usually 6x6-10/10 welded wire fabric is adequate. Calculate the width of wire fabric required based on its circumference, taking into consideration the thickness of the spacers between the pile and reinforcing and allowing at least a 12-inch overlap of the ends.

continued

### Concrete

To determine the amount of concrete required to fill the form, be conservative. When using flexible jackets allow for reduction of concrete volume due to loss of water through the permeable fabric, enlargement of the jacket caused by stretching, and waste. Usually an allowance of 10% extra concrete over the theoretically calculated quantity is sufficient. Contact the ready-mix plant operator well in advance to determine type and amount of concrete and delivery schedule. If ready mix is not available, provide for hauling, stockpiling, and protecting cement, aggregates, clean water, and admixtures, and schedule extra man-hours.

### Form Reinforcing Straps and Special Fittings

Rigid forms usually require reinforcing straps. The spacing and number required depend on the type of form and the hydrostatic pressure of the concrete fill. Some types of reinforcing straps are reusable, but an allowance should be made for a loss of between 10 and 20% of the straps each time they are used. In addition to reinforcing straps, closure forms, blocking hangers, inlet valves, and clamps will be required, the number and type depending on the forming system being used.

Potential Problems: Potential ripping of fabric forms requires familiarity with repair procedures and the availability of repair equipment. Potential unzipping or unlocking of form seams requires familiarity with banding or strapping procedures with form partially full of concrete.

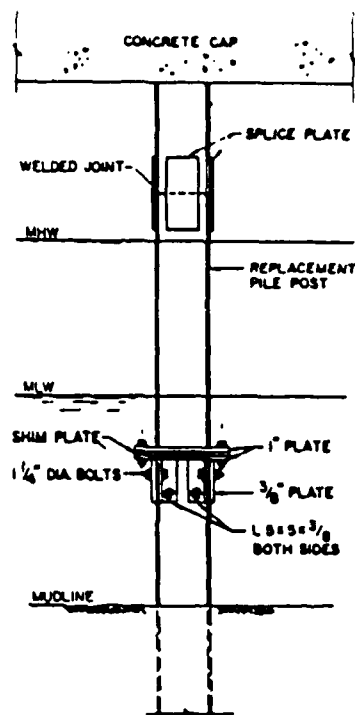


Figure 2-47 - Replacement of Intermediate Section of Steel H-Pile (Ref. 3).

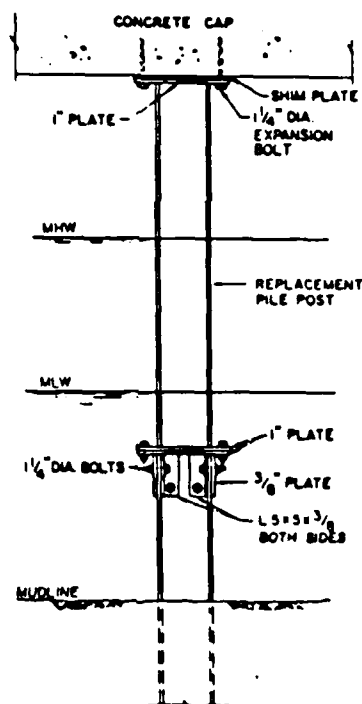


Figure 2-48 - Replacement of Upper Section of Steel H-Pile (Ref. 3).

Table 2-31 - Planning and Estimating Data for Steel Pile Repair Using Partial Replacement (Ref. 3)

Description of Task: Repair a severely deteriorated steel H-pile by replacing a section of the pile from 1 foot above the high water line to 2 feet below the low water line. Total length of repair is 10 to 20 feet. Pile is located near the edge of the structure.

Size of Crew: 2 divers, 1 welder, 2 laborers.

Special Training Requirements: Familiarity with underwater cutting techniques, above-water welding, removal of marine growth, underwater lifting procedures, and drilling procedures.

Equipment Requirements: High-pressure waterblaster, hydraulic grinder with Barnacle Buster attachment, oxygen arc cutting torch equipment, hydraulic drill with bits, hydraulic power unit, rigging gear, crane or lifting equipment, float stage, scaffolding, oxy-acetylene torch equipment, clamp-type template for cutting piles.

Productivity of Crew: 20 hours per pile repair.

Materials:

Replacement Pile Section

The replacement pile section should be long enough to span the measured distance between the bottom cut and the top cut on the damaged pile, minus the thickness of the bearing plates. If replacement is to be performed to the bottom of the concrete deck, allowance must be made for "swinging" room in bringing the pile under the deck, which is taken up by a shim. The best repair will result if the replacement pile is of the same cross section as the existing pile.

Plates

Plate thicknesses will depend on details of splice. Allow for waste.

Angles

Angle sizes will depend on details of splice. Allow for waste.

Bolts

Bolts should be ordered slightly longer than normally required. Expansion bolts are required for some details. Allow for losses due to dropping.

Potential Problems: Since new steel is anodic to old steel, the new steel replacement section has a high susceptibility to corrosion if not protected.

cutting a hole in the decking between existing piles and driving a new pile. Bracing bar may be welded to add lateral stability. A pile cap is formed under the deck and around the new pile, and concrete is placed to fill the form and the space in the deck. Figure 2-49 illustrates the method.<sup>3</sup>

Another method of pile replacement involves an opening in the deck in which a pile is driven at an angle, then laterally placed under the existing pile cap. A shim is placed between pile cap and pile to secure the pile in place. This technique is shown in Figure 2-50.<sup>3</sup>

A new type of filler that has been developed for repair may be used in place of or in combination with concrete in some situations. The name of the product is Instant Road Repair (IRR) developed by Emcol International Limited of Bristol, U.K.

The product is placed into any size, shape or depth hole or crack straight from its 25kg packaging, then spread and compacted. The product consists of 93 percent aggregates (largely granite) and 7 percent Emcol liquid, which is bitumen based with additives, including flexibilisers. IRR has been used at a number of port locations throughout the U.K.

#### 2.5.2.1.6 Coating/Wrapping

To deter natural corrosion from occurring or continuing, the pile may be coated or wrapped. Some types of coatings/wraps are: coal tar, epoxies, polyvinyl chloride. The coatings should be applied from the decking through mean low water.

Planning and estimating data for repair of steel piles using coatings are provided in Table 2-32 and using wrapping in Table 2-33.<sup>3</sup>

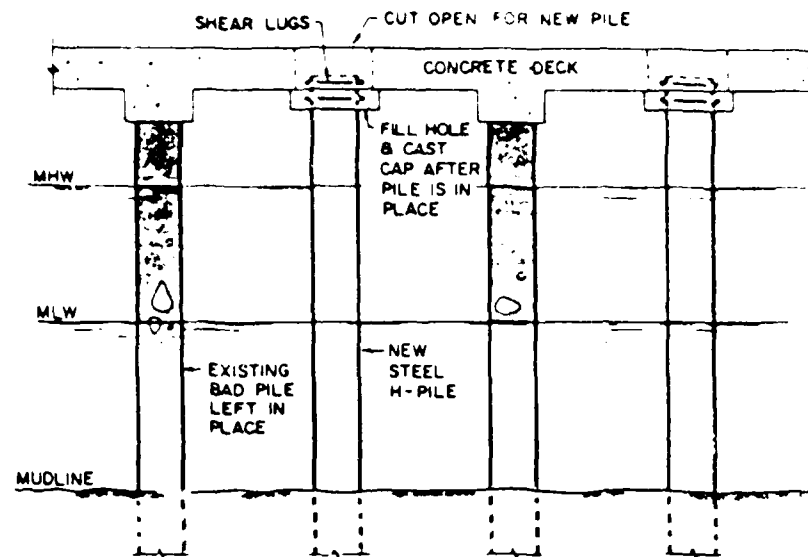


Figure 2-49 - Addition of Steel Piles to Existing Structure With New Pile Cap (Ref. 3).

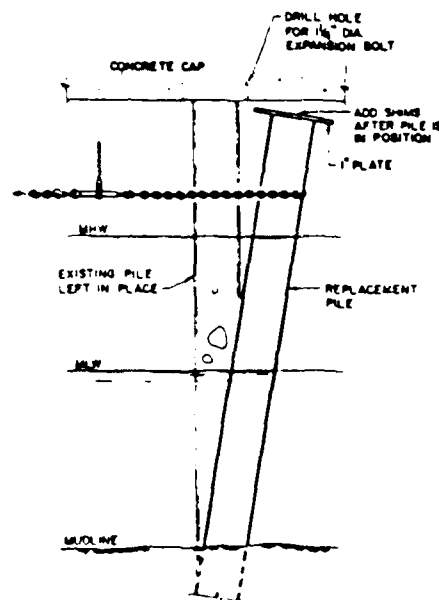


Figure 2-50 - Addition of New Steel Pile to Existing Pile Cap (Ref. 3).

Table 2-32 - Planning and Estimating Data for Steel  
Pile Maintenance Using Wrapping (Ref. 3).

Description of Task: Wrap a steel pipe pile with commercially available polyvinyl chloride (PVC) wrapping sheets from 1 foot above the high water line to 2 feet below the low water line. Total length to be wrapped is 10 to 20 feet.

Size of Crew: 2 divers, 1 laborer.

Special Training Requirements: Familiarity with procedures for removal of marine growth and installation procedure for the PVC pile wrap to be used.

Equipment Requirements: High-pressure waterblaster, hydraulic grinder with Barnacle Buster attachment, high-pressure pump for waterblaster, hydraulic power unit, special fastener tools for pile wrapping (dependent on manufacturer), float stage or work platform.

Productivity of Crew: 3 hours per pile.

Materials:

Polyvinyl Chloride Pile Wrap Unit

Commercially available PVC pile wraps are available in many prefabricated sizes to fit various pile sizes and lengths. Some have separate units for splash zone and underwater use, while others are a single unit. Manufacturers' literature should be consulted before ordering.

Foam Seals, Straps, and Special Fittings

Each pile wrap manufacturer has particular foam seals, fasteners, and special fittings. Manufacturers' literature should be consulted before ordering.

Potential Problems: Projections or sharp edges on the pile may puncture or tear the pile wrap, so care should be taken to remove such problems.

Table 2-33 - Planning and Estimating Data for Steel  
Pile Maintenance Using Coating (Ref. 3).

Description of Task: Coat a steel pipe pile with underwater protective coating from 1 foot above the high water line to 2 feet below the low water line. Total length to be coated is 10 to 20 feet.

Size of Crew: 2 divers, 1 laborer.

Special Training Requirements: Familiarity with procedures for removal of marine growth and application techniques for underwater protective coatings.

Equipment Requirements: High-pressure waterblaster, hydraulic grinder with Barnacle Buster attachment, high-pressure pump for waterblaster, hydraulic power unit, protective clothing and gloves for personnel handling coatings, float stage or work platform.

Productivity of Crew: 4 hours per pile.

Materials:

Epoxy-Polyamide Underwater Coating

Hand-applied underwater protective coatings are usually purchased in two-component kits. A 1-gallon kit might include 1 gallon of each component, resulting in a 2-gallon coverage rate or yield. Coating coverage is measured in square feet per gallon of mixed material. The required coating quantity is obtained by taking the square footage to be covered and dividing by the square foot per gallon coverage rate.

Potential Problems: If water temperature is less than 60°F, proper bonding may not occur. Successful application requires a neutral or positive charge on the structure; negatively charged steel repels the negatively charged epoxy coating. Underwater application may be difficult. Prior to ordering the coating, a sample area of the surface to be coated should be tested under conditions identical to those in which the project will be carried out to be sure that the coating will adhere properly. Skin irritation may occur if individual is sensitive to the epoxy material.

Table 2-34 - Planning and Estimating Data for Steel  
Pile Maintenance Using Cathodic Protection (Ref. 3)

Description of Task: Install a sacrificial anode on a steel pile below low water line. A 40-pound anode is attached to the pile with a welded connection.

Size of Crew: 2 divers, 1 laborer.

Special Training Requirements: Familiarity with removal of marine growth, underwater lifting procedures, and light underwater welding.

Equipment Requirements: High-pressure waterblaster, hydraulic grinder with Barnacle Buster attachment, high-pressure pump for waterblaster, hydraulic power unit, welding machine with leads, welding torch, lift bags/rigging gear, float stage or work platform.

Productivity of Crew: 1/2 hour per anode.

Materials:

Anodes

A sacrificial anode should be placed on each pile to be protected for maximum protection. Wire leads can be run to diagonal or horizontal bracing members between piles and bonded in place for further protection.

#### 2.5.2.1.7 Cathodic Protection

Cathodic protection may be achieved by sacrificial anodes, impressed current or a combination of the two methods. Sacrificial anode systems are those most frequently used. Impressed current systems have shown poor reliability in hostile environment.

Table 2-34 provides planning and estimating data for piles using cathodic protection.<sup>3</sup>

#### 2.5.2.2 Concrete Piles (Existing Concepts)

As with steel piles, concrete pile repair can be categorized into specific groups: concrete encasement, epoxy patching/injection, replacement, wrapping and cathodic protection.

##### 2.5.2.2.1 Concrete Encasement

Concrete encasement is a common repair, like steel, when the material has semi-deteriorated. Both flexible and rigid forms are used extensively. Their function is essentially the same as with steel in Section 2.5.2.1.1 .

Table 2-35 provides planning and estimating data for repair of concrete piles using concrete encasement.<sup>3</sup>

##### 2.5.2.2.2 Epoxy Patching/Injection

The amine-cured epoxies are used extensively for concrete structures. In many cases, epoxy patching is used in localized area of spalling (Fig. 2-51). A hand layup of epoxy coating

reinforced with glass cloth provides an exceptionally heavy coating for immersion services.<sup>4</sup>

Epoxy may also be injected into cracks by using a low viscosity epoxy grout under pressure (Fig. 2-52). Holes are drilled into the area to be grouted so that pump injected epoxy extends to the base of the crack. The drilled holes or ports are plugged so that the epoxy will not filter out. For deeper, longer cracks, an epoxy seal or dam is used to contain the epoxy within the crack.

The use of epoxy in either case warrants a thoroughly clean working surface. The epoxy compound should be limited to no greater than 3/4 of an inch in thickness. This is due to the different expansion rates from temperature changes.

Planning and estimating data for repair of concrete piles using epoxy patching are provided in Table 2-36 and using epoxy injection in Table 2-37.<sup>3</sup>

#### **2.5.2.2.3 Replacement**

Concrete piles may need to be replaced rather than repaired. In this case, a technique for concrete pile replacement is the same as steel pile replacement.

#### **2.5.2.2.4 Wrapping**

Piles wrapped with polyvinyl chloride (PVC) sheet are more resistant to abrasion and pitting by chemical action because there is no direct action by seawater on the pile. Table 2-38 provides planning and estimating data for repair of concrete piles using wrappings.

#### 2.5.2.2.5 Corrosion Protection

Concrete surface can be treated chemically to densify and harden the exterior (fluoride treatments on sodium silicate

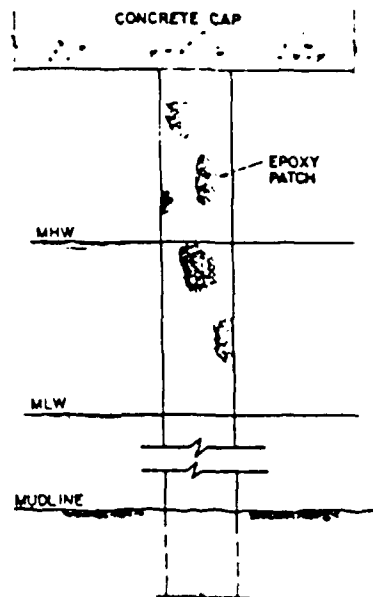


Figure 2-51 - Epoxy Patching of Concrete Pile (Ref. 3).

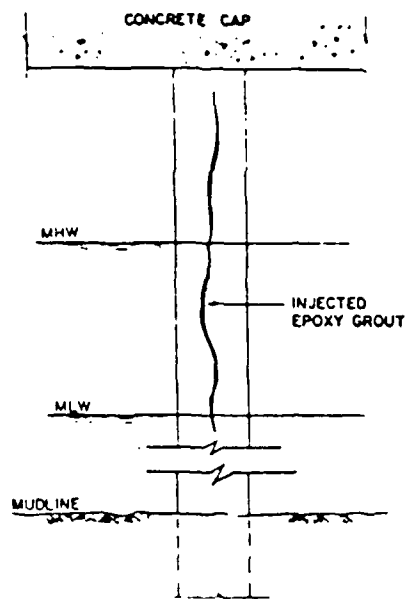


Figure 2-52 - Epoxy Grouting of Concrete Pile (Ref. 3).

Table 2-35 - Planning and Estimating Data for Concrete Pile Repair Using Concrete Encasement (Ref. 3).

Description of Task: Repair a deteriorated concrete pile by installing a concrete encasement from 1 foot above the high water line to 2 feet below the mud line. The total length of encasement is 20 to 30 feet. Reinforcement of the pile is not required.

Size of Crew: 2 divers, 2 laborers.

Special Training Requirements: Familiarity with the type of jacket to be used for the concrete form, concrete pump operation, jetting or air lifting procedures, and removal of marine growth.

Equipment Requirements: High-pressure waterblaster, hydraulic grinder with Barnacle Buster attachment, hydraulic power unit, concrete pump with adequate hose, concrete mixer (if ready-mix concrete is not available), jetting pump and hose, rigging equipment, float stage, scaffolding.

Productivity of Crew: 6 hours per pile repair.

Materials:

Form Material

Either flexible or rigid forms may be used. When using proprietary forms, follow manufacturers' recommendations regarding lengths and diameter of forms, top and bottom closures, spacers, bands, straps, and special fittings. Forms are ordered prefabricated in the required length and diameter. For flexible forms, allowance on the length must be made for extra fabric that may be required around blocking at the top and bottom of the jacket. Some proprietary systems require that different types of forms be used in the tidal and submerged zones.

Spacers

A conservative estimate of the number of spacers must be made. In calm water and with vertical piles, relatively few spacers will be required. Rough water and batter piles will require more spacers.

Wire Mesh Reinforcing

Usually 6x6-10/10 welded wire fabric is adequate. Calculate the width of wire fabric required based on its circumference, taking into consideration the thickness of the spacers between the pile and reinforcing and allowing a 9-inch overlap of the ends.

continued

### Concrete

To determine the amount of concrete required to fill the form, be conservative. When using flexible jackets allow for reduction of concrete volume due to loss of water through the permeable fabric, enlargement of the jacket caused by stretching, and waste. Usually an allowance of 10% extra concrete over the theoretically calculated quantity is sufficient.

### Form Reinforcing Straps and Special Fittings

Rigid forms usually require reinforcing straps. The spacing and number required depend on the type of form and the hydrostatic pressure of the concrete fill. Some types of reinforcing straps are reusable, but an allowance should be made for a loss of between 10 and 20% of the straps each time they are used. In addition to reinforcing straps, closure forms, blocking hangers, inlet valves, and clamps will be required, the number and type depending on the forming system being used.

Potential Problems: Potential ripping of fabric forms requires familiarity with repair procedures and the availability of repair equipment. Potential unzipping or unlocking of form seams requires familiarity with banding or strapping procedures with form partially full of concrete.

Table 2-36 - Planning and Estimating Data for Concrete  
Pile Repair Using Epoxy Patching (Ref. 3).

Description of Task: Repair a deteriorated concrete pile by patching with hand-applied epoxy. Unit area to be repaired is 1 ft<sup>2</sup> underwater.

Size of Crew: 2 divers, 1 laborer.

Special Training Requirements: Familiarity with procedures for removal of marine growth and application of epoxy patching compounds underwater.

Equipment Requirements: High-pressure waterblaster, hydraulic grinder with Barnacle Buster attachment, high-pressure pump for waterblaster, hydraulic power unit, protective clothing for personnel handling the epoxy patching compound, float stage or work platform.

Productivity of Crew: 15 min/ft<sup>2</sup> underwater.

Materials:

Epoxy Patching Compound

Epoxy patching compounds are usually purchased in two-component kits, with an aggregate additive. A 1-gallon kit might include 1 gallon of each component plus aggregate, resulting in more than a 2-gallon yield. Patching coverage is measured in square feet per gallon. The required patching yield is obtained by taking the square footage to be covered and dividing by the square foot per gallon coverage rate.

Potential Problems: If water temperature is less than 60°F, proper adhesion to the pile may not occur. Skin irritation may occur if individual is sensitive to the epoxy material.

Table 2-37 - Planning and Estimating Data for  
Pile Repair Using Epoxy Injection (Ref. 1)

Description of Task: Repair a 6-inch-deep crack in a concrete pile by injecting low-viscosity neat epoxy grout into the crack. Total length of crack to be repaired is 10 feet.

Size of Crew: 2 divers, 1 laborer.

Special Training Requirements: Familiarity with procedures for removal of marine growth, the use of epoxy grout pump, and the use of injectable epoxy.

Equipment Requirements: High-pressure waterblaster, hydraulic grinder with Barnacle Buster attachment, hydraulic drill with bits, high-pressure pump for waterblaster, hydraulic power unit, protective clothing for personnel handling the epoxy compound, epoxy pump, float stage or work platform.

Productivity of Crew: 10 min/linear ft of crack.

Materials:

Low-Viscosity Epoxy Grout

Commercially available injectable epoxy grouts are usually purchased in two-component kits. Mixing proportions will vary, so manufacturers' instructions should be followed. The volume of the crack must be estimated by taking its length, average width, and average depth. An additional 25% should be added to allow for overfilling of the cracks and inaccuracies in estimating the size of the cracks.

Potential Problems: If water temperature is less than 60°F, proper adhesion to the pile may not occur. Skin irritation may occur if individual is sensitive to the epoxy material.

Table 2-38 - Planning and Estimating Data for Concrete  
Pile Maintenance Using Wrapping (Ref. 3).

Description of Task: Wrap a concrete pile with commercially available polyvinyl chloride (PVC) wrapping sheets from 1 foot above the high water line to 2 feet below the low water line. Total length to be wrapped is 10 to 20 feet.

Size of Crew: 2 divers, 1 laborer.

Special Training Requirements: Familiarity with procedures for removal of marine growth and with installation procedure for the PVC pile wrap to be used.

Equipment Requirements: High-pressure waterblaster, hydraulic grinder with Barnacle Buster attachment, high-pressure pump for waterblaster, hydraulic power unit, special fastener tools for pile wrapping (dependent on manufacturer), float stage or work platform.

Productivity of Crew: 3 hours per pile.

Materials:

Polyvinyl Chloride Pile Wrap Unit

Commercially available PVC pile wraps are available in many prefabricated sizes to fit various pile sizes and lengths. Some have separate units for splash zone and underwater use, while others are a single unit. Manufacturers' literature should be consulted before ordering.

Strap and Special Fittings

Each pile wrap manufacturer has particular fasteners and special fittings. Manufacturers' literature should be consulted before ordering.

Potential Problems: Projections or sharp edges on the pile may puncture or tear the pile wrap, so care should be taken to remove such problems.

washes) as a mode of corrosion protection. Another type of exterior seal is bituminous coatings. Epoxy coatings are the most compatible with concrete as discussed in the epoxy patching section.

Reinforcing steel should also be protected from corrosion, or cracking and disintegration of the concrete will occur as the corrosion products expand. Rebar should be coated with an epoxy or zinc-rich paint before casting.

Cathodic protection of rebar can be applied if the metal structure is continuous. This means that all rebars must be joined in some fashion.

#### **2.5.2.3 Timber Piles (Existing Concepts)**

There are several methods for the repair of timber piles: concrete encasement, partial replacement, complete replacement.

##### **2.5.2.3.1 Concrete Encasement**

As with steel piles, timber piles may also be encased with concrete. This method restores damaged timber piles to almost original strength.

Flexible and rigid form types are used in the same manner as with steel. This technique helps protect the piles from abrasion as well as marine borers. Table 2-39 provides planning and estimating data for repair of timber piles using concrete encasement.<sup>2</sup>

##### **2.5.2.3.2 Partial Replacement**

There are several methods devised which involve sectional replacement of damaged piles. These methods include posttensioning and

fish plating. A problem that occurs with partial replacement is the general attack of marine borers to cut timber. It is suggested that PVC Wrap and/or creosote be used. Planning and estimating data for repair of timber piles by posting to the mud line are provided in Table 2-40 and by fish plating to below the low water line in Table 2-41.<sup>3</sup>

#### **2.5.2.3.3 Posting Techniques**

The two popular posting techniques used are the drift pin (Figure 2-53) and the pipe sleeve (Figure 2-54) method. The drift pin method excavates the soil around the driver section of pile where in the pile is cut below the mud line. The damaged section is removed and replaced with a new section. This section is attached to the sound timber pile with galvanized drift pins and the pile cap with shims and galvanized bolts.

The pipe sleeve method is the same as the drift pin except that rather than using drift pins, a bottom joint is created using a pipe sleeve. Boat spikes are used to hold the sleeve in place. At the decking, the new pile is shimmed tight against the pile cap and secured with drift pins.

#### **2.5.2.3.4 Fish Plating Technique**

Figure 2-55 illustrates the fish plating technique.<sup>3</sup> This method uses small timber sheets to be used as splices for connections between new and old timber members. Structural bolts are used to connect the new member at the pile butt and at the pile cap.

#### **2.5.2.3.5 Complete Replacement**

Piles that are severely deteriorated may be more economically replaced rather than repaired. Replacement techniques are the same as steel pile replacement.

Table 2-39 - Planning and Estimating Data for Timber  
Pile Repair Using Concrete Encasement (Ref. 3)

Description of Task: Repair a deteriorated timber pile by installing a concrete encasement from 1 foot above the high water line to 2 feet below the mud line. The total length of encasement is 20 to 30 feet. Reinforcement of the pile is not required.

Size of Crew: 2 divers, 2 laborers.

Special Training Requirements: Familiarity with the type of jacket to be used for the concrete form, concrete pump operation, jetting or air lifting procedures, and removal of marine growth.

Equipment Requirements: High-pressure waterblaster, hydraulic grinder with Barnacle Buster attachment, hydraulic power unit, concrete pump with adequate hose, concrete mixer (if ready-mix concrete is not available), jetting pump and hose, rigging equipment, float stage, scaffolding.

Productivity of Crew: 6 hours per pile repair.

Materials:

Form Material

Either flexible or rigid forms may be used. When using proprietary forms, follow manufacturers' recommendations regarding lengths and diameter of forms, top and bottom closures, spacers, bands, straps and special fittings. Forms are ordered prefabricated in the required length and diameter. For flexible forms, allowance on the length must be made for extra fabric that may be required around blocking at the top and bottom of the jacket. Some proprietary systems require that different types of forms be used in the tidal and submerged zones.

Spacers

A conservative estimate of the number of spacers must be made. In calm water and with vertical piles, relatively few spacers will be required. Rough water and batter piles will require more spacers.

continued

### Wire Mesh Reinforcing

Usually 6x6-10/10 welded wire fabric is adequate. Calculate the width of wire fabric required based on its circumference, taking into consideration the thickness of the spacers between the pile and reinforcing and allowing a 9-inch overlap of the ends.

### Concrete

To determine the amount of concrete required to fill the form, be conservative. When using flexible jackets allow for reduction of concrete volume due to loss of water through the permeable fabric, enlargement of the jacket caused by stretching, and waste. Usually an allowance of 10% extra concrete over the theoretically calculated quantity is sufficient.

### Form Reinforcing Straps and Special Fittings

Rigid forms usually require reinforcing straps. The spacing and number required depend on the type of form and the hydrostatic pressure of the concrete fill. Some types of reinforcing straps are reusable, but an allowance should be made for a loss of between 10 and 20% of the straps each time they are used. In addition to reinforcing straps, closure forms, blocking hangers, inlet valves, and clamps will be required, the number and type depending on the forming system being used.

Potential Problems: Potential ripping of fabric forms requires familiarity with repair procedures and the availability of repair equipment. Potential unzipping or unlocking of form seams requires familiarity with banding or strapping procedures with form partially full of concrete.

Table 2-40 - Planning and Estimating Data for Timber  
Pine Repair Using Partial Replacement to Mud Line (Ref.  
3) -

Description of Task: Repair a severely deteriorated timber pile by posting to the mud line with a new pile butt connected with a pipe sleeve at the base of the replacement section. Total length of repair is 10 to 30 feet. Pile is located near the edge of the structure.

Size of Crew: 2 divers, 2 laborers.

Special Training Requirements: Familiarity with underwater cutting techniques, procedures for removal of marine growth, jetting or air lifting procedures, underwater lifting procedures, and drilling procedures.

Equipment Requirements: High-pressure waterblaster, hydraulic grinder with Barnacle Buster attachment, hydraulic drill with bits, hydraulic power unit, air lift or jetting pump and hose, rigging equipment, crane or lifting equipment, float stage, oxy-acetylene torch equipment, clamping template for cutting piles, and hydraulic chain saw.

Productivity of Crew: 10 hours per pile.

Materials:

Replacement Pile Section

The replacement pile section should be long enough to span the measured distance between the bottom cut and the top cut on the damaged pile. If replacement is to be performed to the bottom of the concrete deck, allowance must be made for "swinging" room in bringing the pile under the deck and a shim installed to fill the gap.

Pipe Sleeve

The pipe sleeve is required to provide a moment resisting connection at the base of the repair. The diameter of the pipe sleeve must be sufficiently large to accept both the existing pipe and the replacement section. The minimum length of the pipe sleeve should be 3 feet.

Connection Hardware

Connection hardware will depend on the details of the repair. Allow for losses due to dropping.

Potential Problems: All load must be removed from the existing pile before it is cut to avoid jamming the saw. Greosote will ruin a wet suit and may cause skin irritation.

Table 2-41 - Planning and Estimating Data for Timber  
Pile Repair Using Partial Replacement to Below Low  
Water Line (Ref. 3)

Description of Task: Repair a severely deteriorated timber pile by posting to 2 feet below the low water line with a new pile butt connected by a fish plate splice at the base of the replacement section. Total length of repair is 10 to 20 feet.

Size of Crew: 2 divers, 2 laborers.

Special Training Requirements: Familiarity with underwater cutting techniques, procedures for removal of marine growth, underwater lifting procedures, and drilling procedures.

Equipment Requirements: High-pressure waterblaster, hydraulic grinder with Barnacle Buster attachment, hydraulic drill with bits, hydraulic power unit, rigging gear, crane or lifting equipment, float stage, oxy-acetylene torch equipment, clamping template for cutting piles, and hydraulic chain saw.

Productivity of Crew: 8 hours per pile.

Materials:

Replacement Pile Section

The replacement pile section should be long enough to span the measured distance between the bottom cut and the top cut on the damage pile. If replacement is to be performed to the bottom of the concrete deck, allowance must be made for "swinging" room in bringing the pile under the deck and a shim installed to fill the gap.

Connection Hardware

Connection hardware will depend on the details of the repair. The attachment to the pile cap should include a minimum of two bolts. The fish plate splice should include a minimum of two bolts through each side of the splice, for a total of four bolts. Bolts should be ordered slightly longer than calculated to allow for oversized piles. Allow for losses due to dropping.

Fish Plate

The fish plates are used in pairs, one on each side of the repair, and are made of 4- by 10-inch treated timber. The minimum length of each fish plate is about 3 feet.

Potential Problems: If the connection is weak in resisting moments, the connection should be made so that it is strongest in the direction of the side loading. All load must be removed from the existing pile before it is cut to avoid jamming the saw. Creosote will ruin a wet suit and may cause skin irritation.

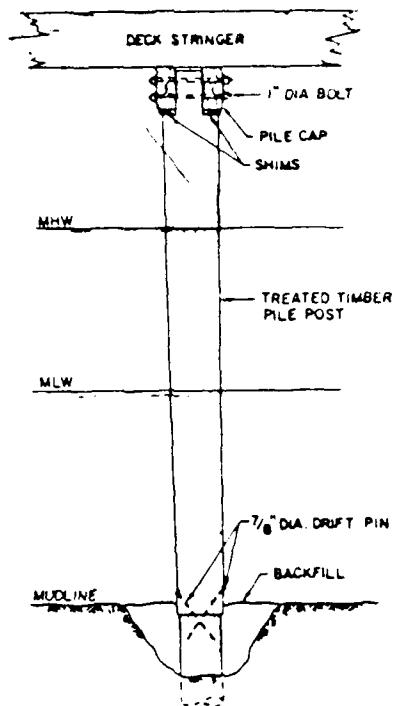


Figure 2-53 - Posting of Timber Pile Using Drift Pins (Ref. 3)

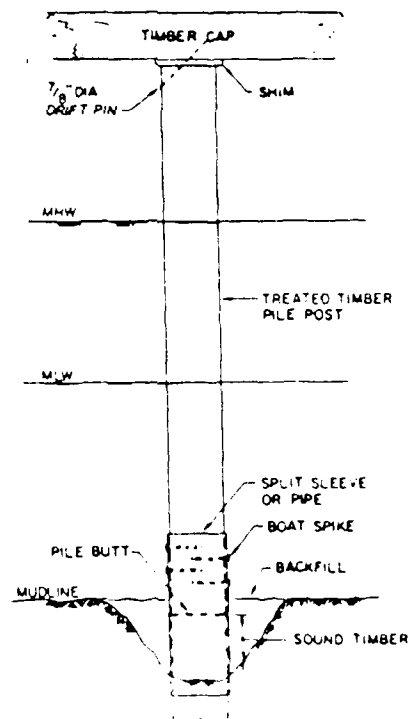


Figure 2-54 - Posting of Timber Pile Using Pipe Sleeve (Ref. 3).

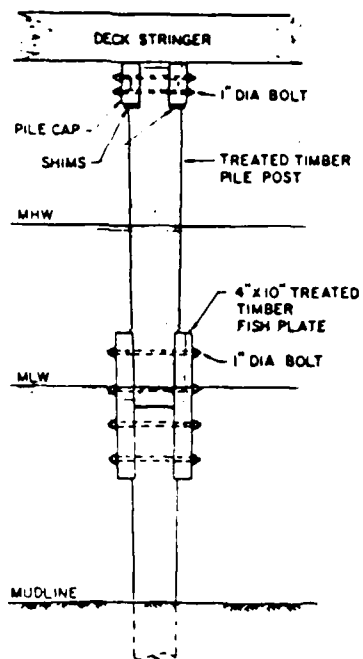


Figure 2-55 - Posting of Timber Pile Using Fish Plates  
(Ref. 3).

#### 2.5.2.3.6 Wrapping

Polyvinyl chloride (PVC) sheets are a widely used technique for the protection of timber piles. This helps to prevent further marine borering and to destroy already existing borers within the pile. There are two commonly used PVC systems: two unit wrap (Figure 2-56) and single unit wrap (Figure 2-57).

The two-unit pile wrap system, uses an upper intertidal unit starting at least 1 foot above mean high water and extending to at least 3 feet below mean low water. The lower unsealed unit overlaps the intertidal unit and extends to below the mud line. Polyurethane foam seals are used at each end of the intertidal unit to ensure air and water tightness.

The single-unit method uses a single jacket that extends the full length of the section of the pile to be protected.

#### 2.5.2.4 New Conceptual Designs for Piling

The following design is conceptual and merits further evaluation.

##### 2.5.2.4.1 Shoring Pile

A shoring pile (Figure 2-58) would be used as a partial replacement. The damaged section of pile is cut out wherein a pile connector is fitted, or an assembly is used to incorporate steel bearing plates. A internal screw is wound upward by use of a pile wrench which makes contact with a shim and pile cap. By tightening the screw, the shoring pile begins to carry the axial load from the decking.

### 2.5.3 PIER AND WHARF DECKING (EXISTING CONCEPTS)

This section discusses possible solutions for pier damage, specifically the decking. The following is a general description of expedient repairs developed in Reference 9, which include: steel beam concept, erector set concept, steel beam mat concept, steel beam and timber deck concept, steel beam and steel bar grate concept. Reference 9 should be consulted for detailed information and calculations.

#### 2.5.3.1 Steel Plate Concept

When examining expedient repair for decking, simplicity and ease of installation should be observed. Steel plates are a means to cover a damaged area of a pier quickly and easily. Reference 9 states that 10 Kip steel plates can be selected from a stack, loaded onto a truck, unloaded and placed in 1.5 hr. Depending on the size of the crater, plate size may vary. This mainly depends upon the loads that the plate is subject to.

Figure 2-59 shows the use of steel plates that are 8'x10'x2" to cover damage.<sup>9</sup> Steel plates may be maneuvered into place by vehicles rather than cranes. To hold the plates in place, a system of bolts may be used or welded slabs of metal perpendicular to the plate to constrain lateral movement. Figure 2-60 illustrates moment capacity of steel plates of various strengths.

For design and comparison calculations, see Appendix D of Reference 9.

#### 2.5.3.2 Erector Set Concept

Another type of method which integrates the use of wide flange beams and 1-inch steel plates bolted to both flanges

(Figure 2-61). This creates a larger moment carrying capacity. Designs are developed for two types of repair modules. Type A modules are similar to the cross section in Figure 2-62 (Ref. 10). Type B modules are Type A modules without the bottom plate. Type A or Type B modules are installed as shown in Figure 2-63 (Ref. 10). A total of 50 to 100 manhours and 24 scheduled hours are consumed for a complex repair.

#### **2.5.3.3 Steel Beam Mat Concept**

The concept of the steel beam mat illustrated in Figure 2-64, is to lay wide flange steel beams side by side to be used as a bridge. According to Reference 9, the flanges of the beams will be 1 foot wide and would only be sufficiently bolted together enough to prevent lateral movement. The scheduled time and manhours are one-third those of the erector set concept. For detailed design and comparison calculations, see Appendix D of Reference 9.

#### **2.5.3.4 Steel Beam and Timber Concept**

Figures 2-65 and 2-66 illustrate two possible designs for timber and steel repair concepts (Ref. 10). This type of system shows great interest due to ease of access to materials. Disadvantages to the first method are that the edges of the crater have to be cleaned, slingers must be attached to the underside of the deck, and pre-assembly is not possible. Method 2 is more feasible in respect that the beams are laid on the deck and pre-assembly is possible. Calculations and designs are shown in Appendix D of Reference 9.

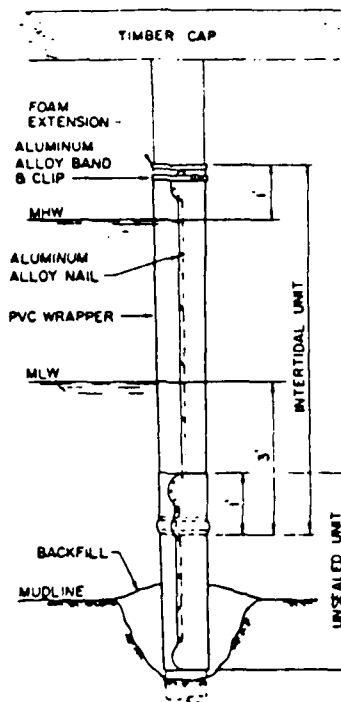


Figure 2-56 - Two-unit Pile Wrap (Ref. 3).

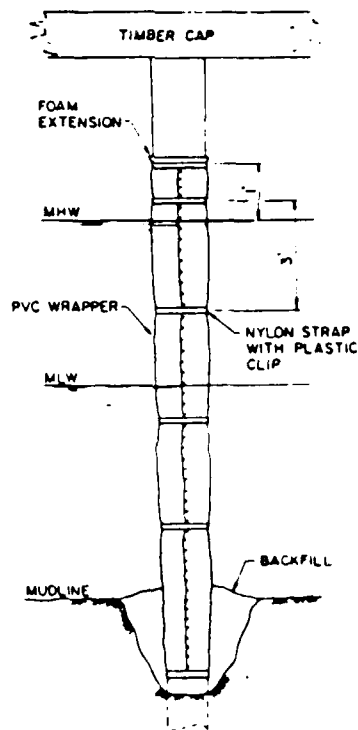


Figure 2-57 - Single Unit Timber Pile Wrap (Ref. 3).

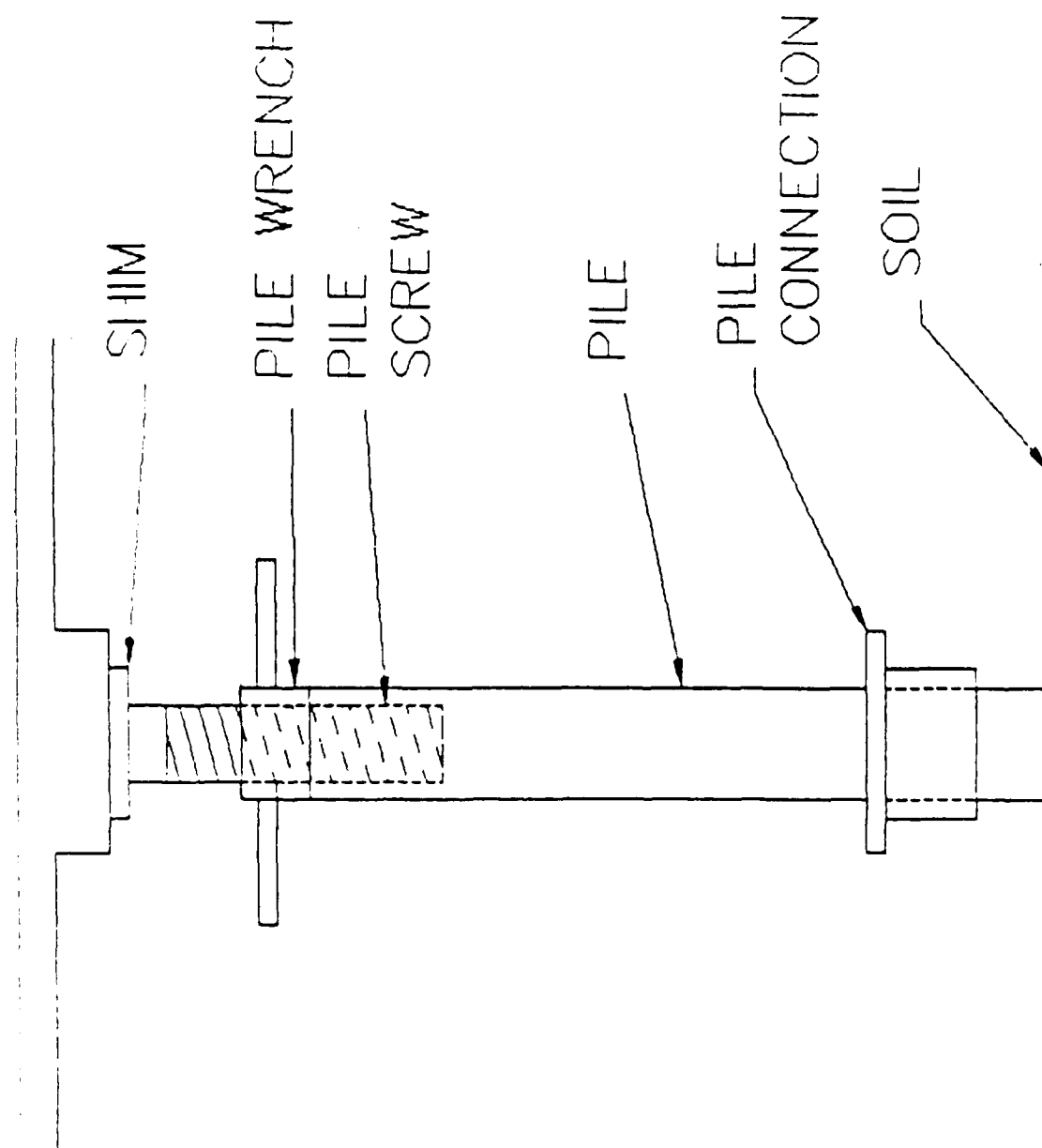


Figure 2-58 - Shoring Pile.

#### 2.5.3.5 Steel Beam and Steel Bar Grate Concept

In replacement of timber decks is steel bar grate. Interlocking grating is a possible choice due to its high strength and durability. The disadvantage is that bar grate has only one way structural resistance, and composite action cannot be developed between the bar grate and supporting beams. Design and comparison calculations are found in Appendix D of Reference 9.

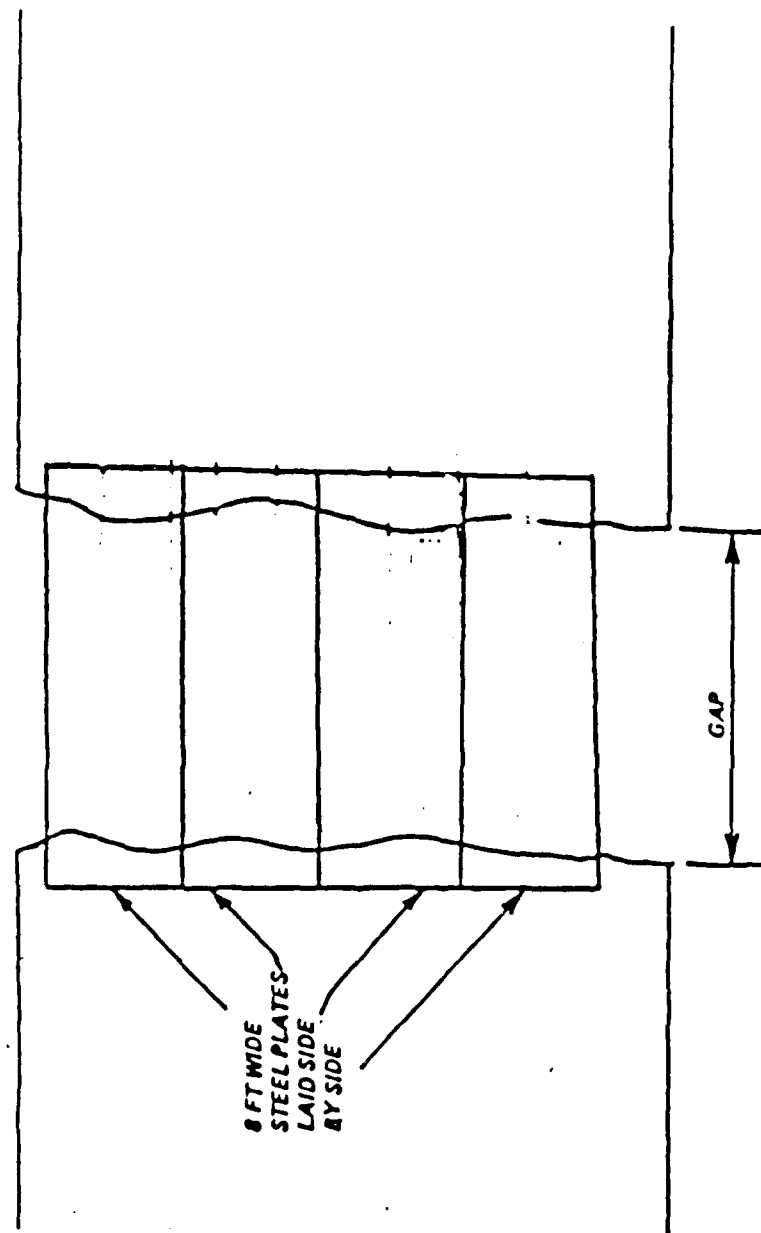


Figure 2-59 - Steel Plate Method (Ref. 10).

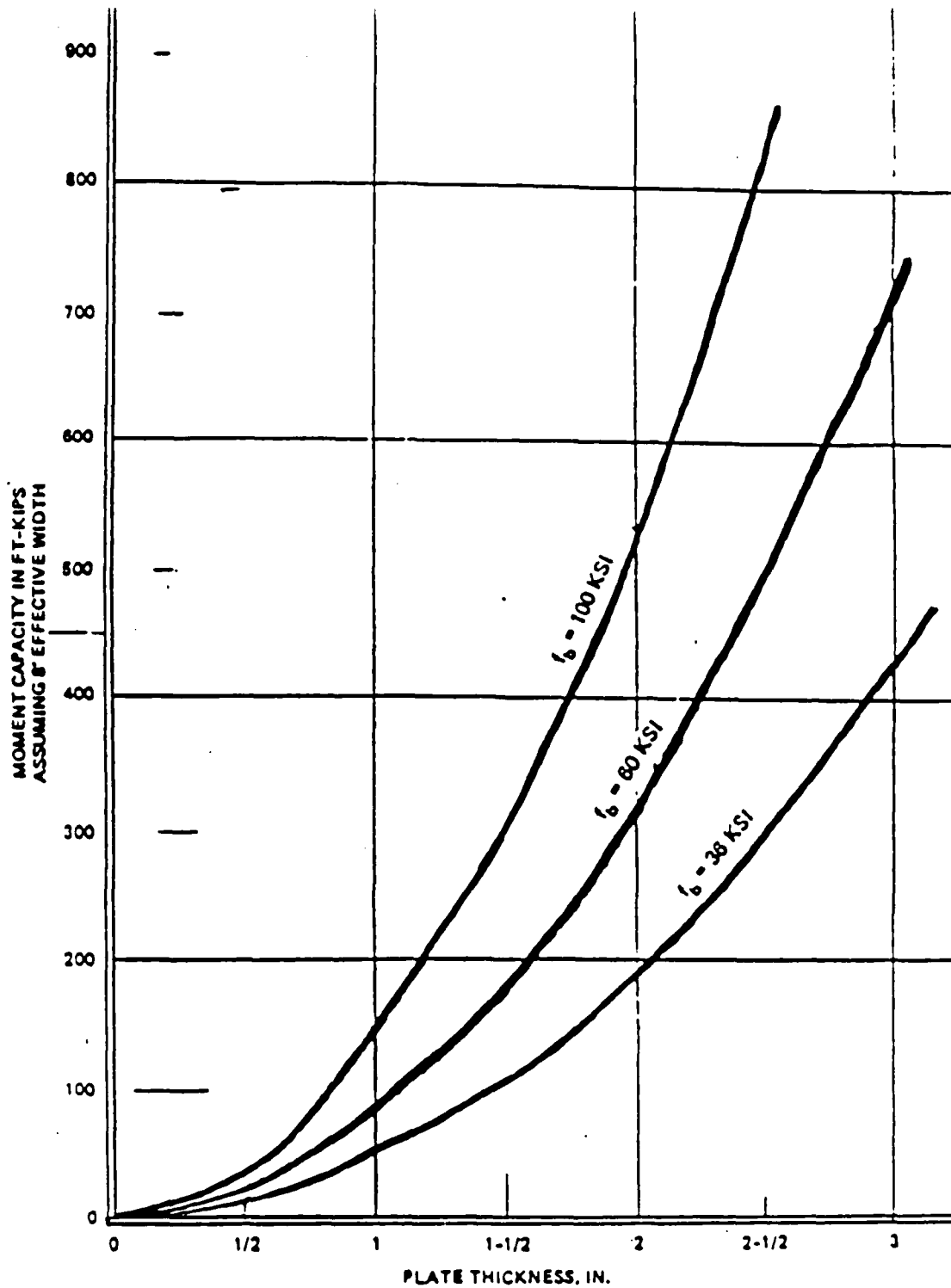


Figure 2-60 - Moment Capacity of Steel Plates of Various Strengths (Effective Width Equals 3 ft.) (Ref. 10).

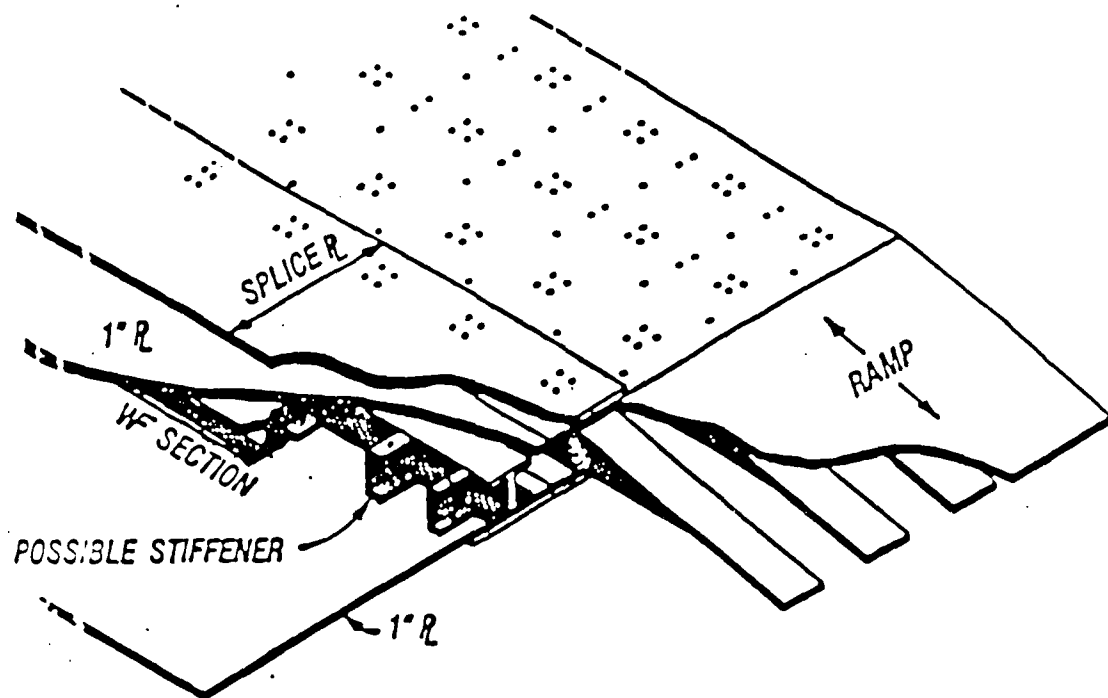


Figure 2-61 - Isometric View of Type A Module (Ref. 10)

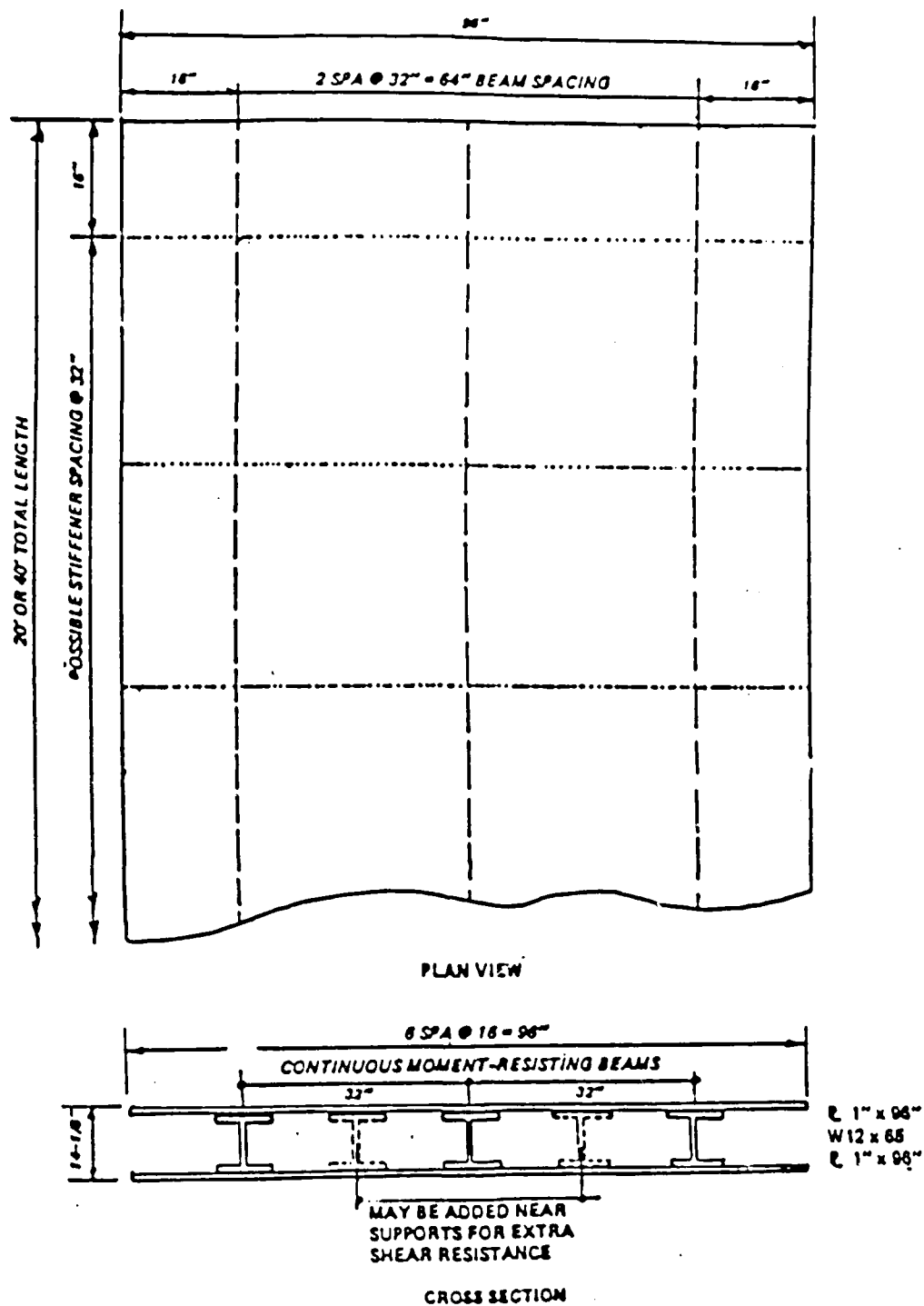
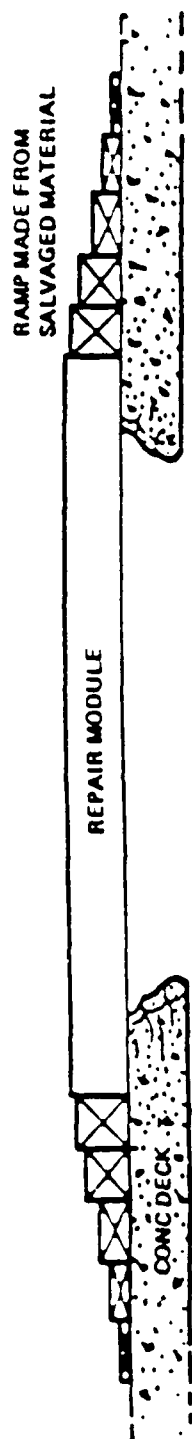
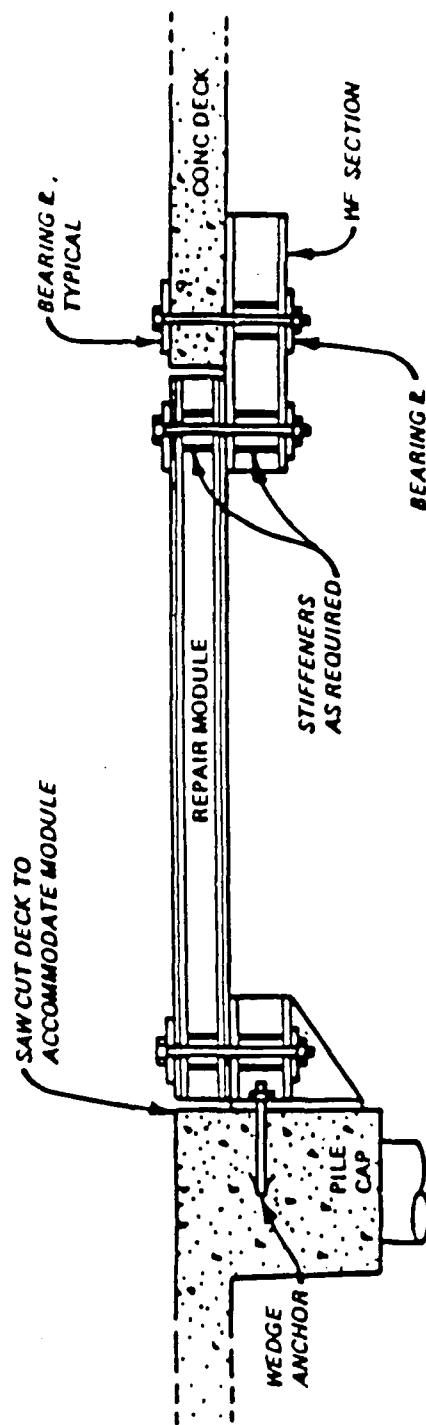


Figure 2-62 - Plan and Cross Section, Type A Repair Module (Ref. 10).



a. Repair module laid on top of deck to cover damage



b. Flush repair using repair module

Figure 2-63 - Alternate Installation Methods for Repair Modules (Ref. 10).

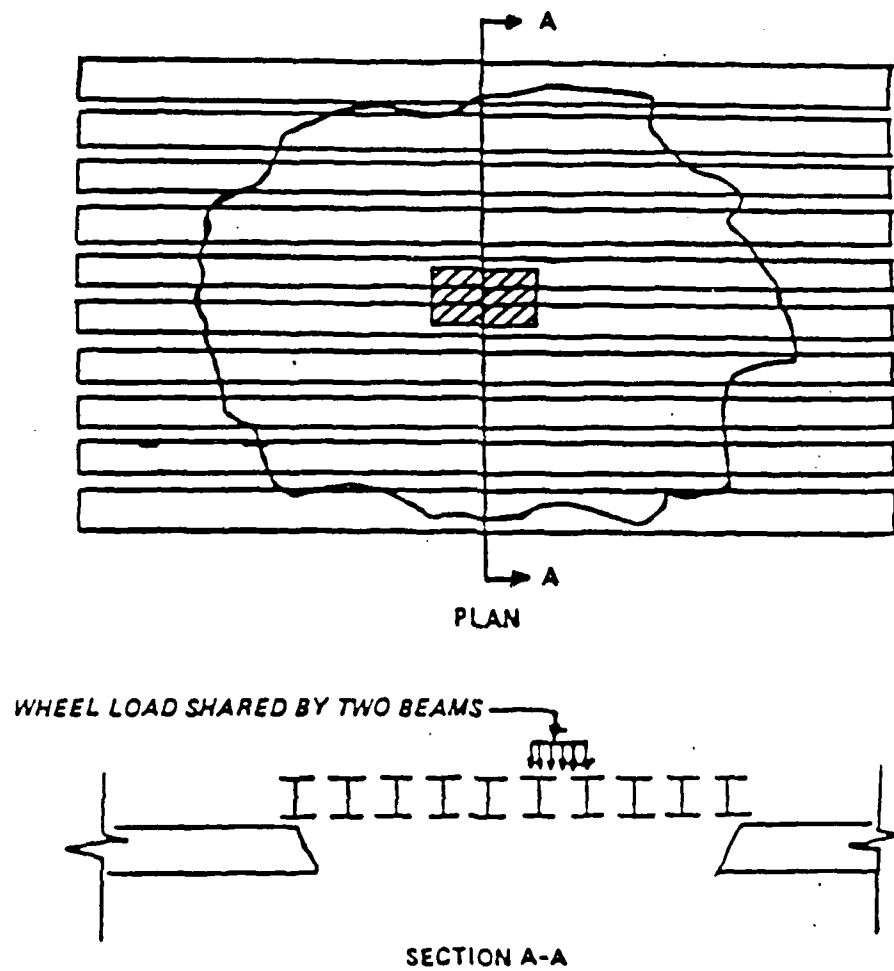


Figure 2-64 - Steel Beam Mat Concept Repair (Ref. 10).

#### 2.5.3.6 New Concepts

The following designs are conceptual and merit further evaluation. The two types examined are used in other fields of structural design but may be used for waterfront repair.

#### 2.5.3.7 King Post Truss

The king post truss assembly (Figure 2-67) is a technique used to add strength to a weakened floor or deck. The beam truss or king post truss adds support by the tightening of the threaded rods. This creates an opposite reaction force to the load which is transferred to a plate that acts over a larger area. By pushing upward on the lessened capacity decking, strength is returned to support the loads.

#### 2.5.3.8 Isolation Bearing

This type of bearing is mainly used in areas of seismic activity. The possibility of use could be with the pile/pilecap interface. Figure 2-68 illustrates an isolation bearing.

The bearing is a rectangular block of material, ozone-resistant rubber with cylindrical cores of pure lead. To provide vertical stiffness to the bearing from inhibiting side bulging, closely spaced horizontal sheet steel laminations (shims) are bonded to the rubber during fabrication.

Under small lateral loads and movements, the lead provides most of the lateral stiffness and behaves elastically. However, under sufficiently large loads the lead yields, and the bearing's lateral stiffness is then provided by the rubber alone.

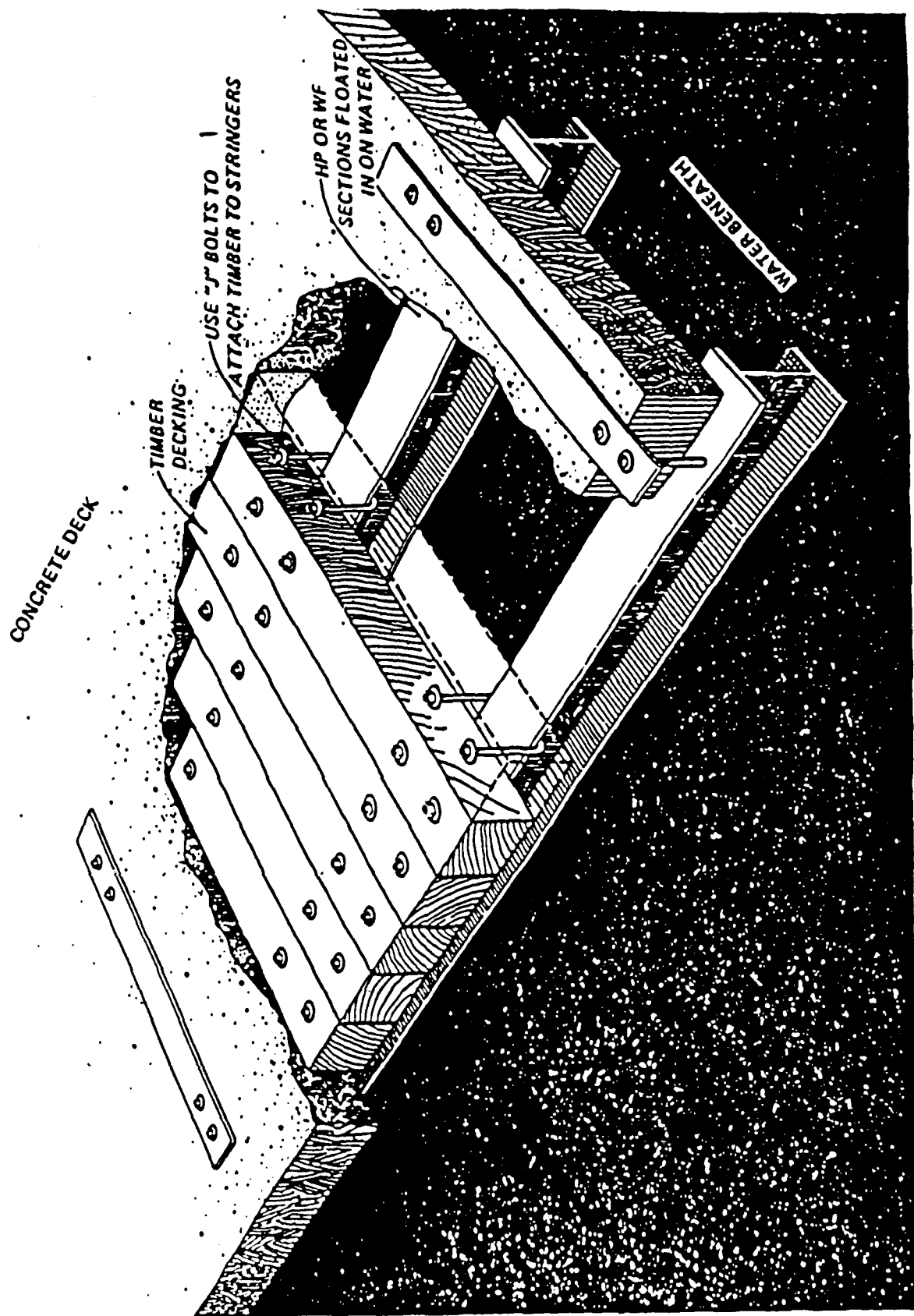


Figure 2-65 - Underslung Steel Beam and Timber Deck Repair (Ref. 10).

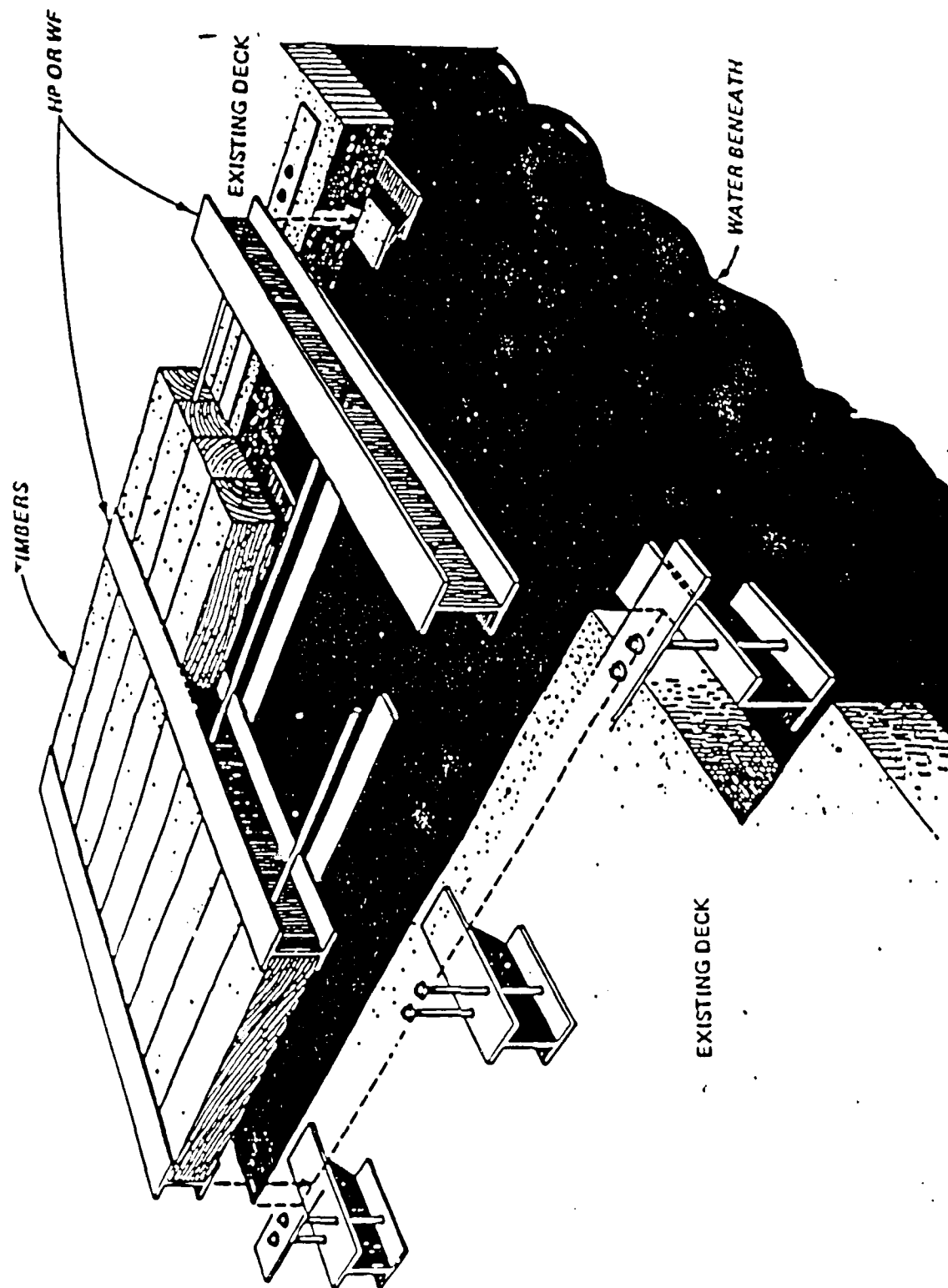


Figure 2-66 - Prefabricated Timber and Steel Deck Panels (Ref. 10).

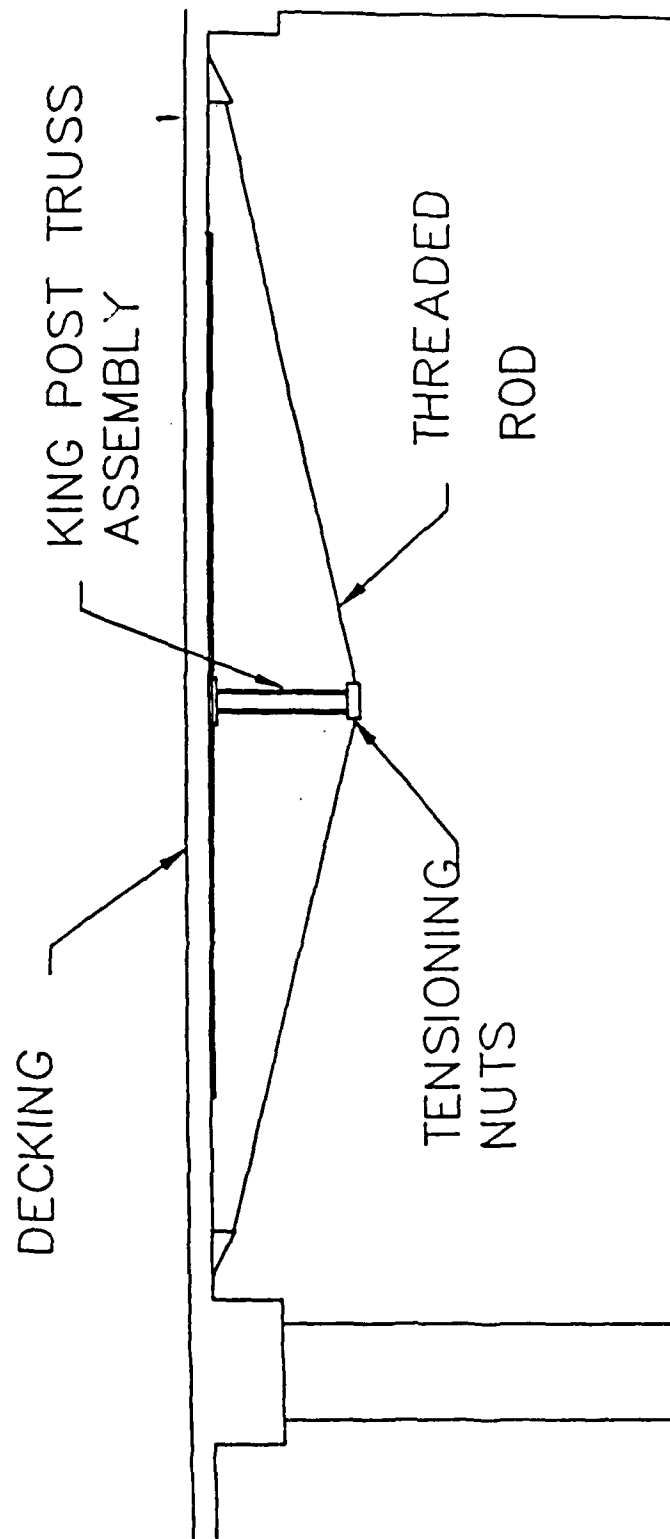


Figure 2-67 - King Post Truss.

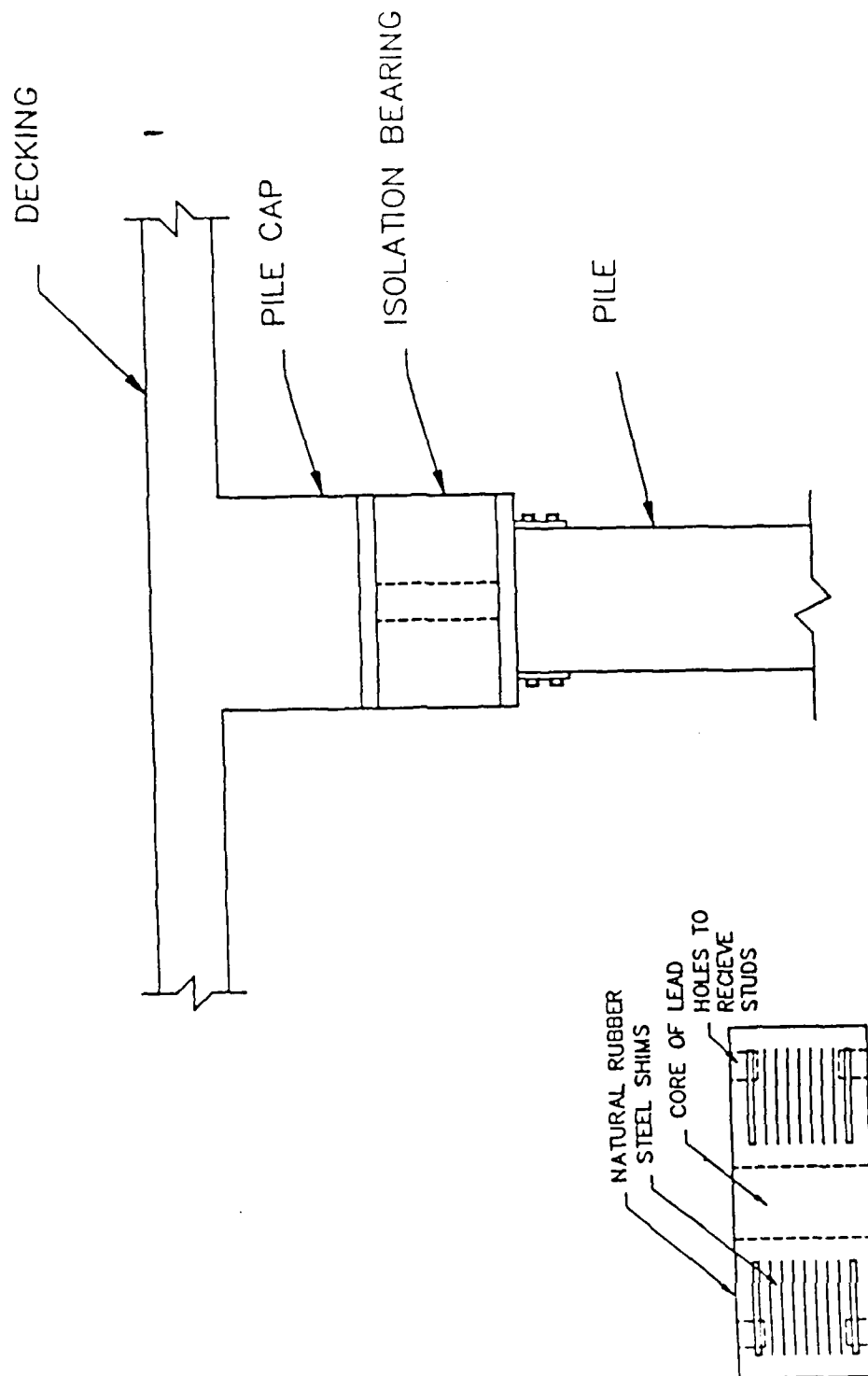


Figure 2-68 - Isolation Bearing.

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APPENDIX

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APPENDIX A

Table 1. Potential Application of NDT Techniques for Underwater Inspection

	Material			Type of Structure					Type of Defect				
	Metal	Concrete	Wood	Seawall	Piling	Mooring Elements	Pipeline	Offshore Towers	Metal Thickness	Surface Cracks	Weld Defect	Galvanic Potential	Internal Crack or Void Inclusions
Ultrasonic Inspection	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Magnetic Particle	Yes	No	No	No	(2)	(1)	Yes	Yes	No	Yes	(3)	No	No
Radiography	Yes	Yes	Yes	No	Yes	Yes	(4)	(4)	(5)	(5)	Yes	No	Yes (5)
Eddy Current	Yes	No	No	Yes	(1&2)	(1)	(1)	(1)	Yes	Yes	No	No	Yes
Underwater Electrical Potential	Yes	No	No	Yes (2)	Yes (2)	Yes	Yes (2)	Yes	No	No	No	Yes	No

(1) Not normally used for this application.

(2) Depends on type of material.

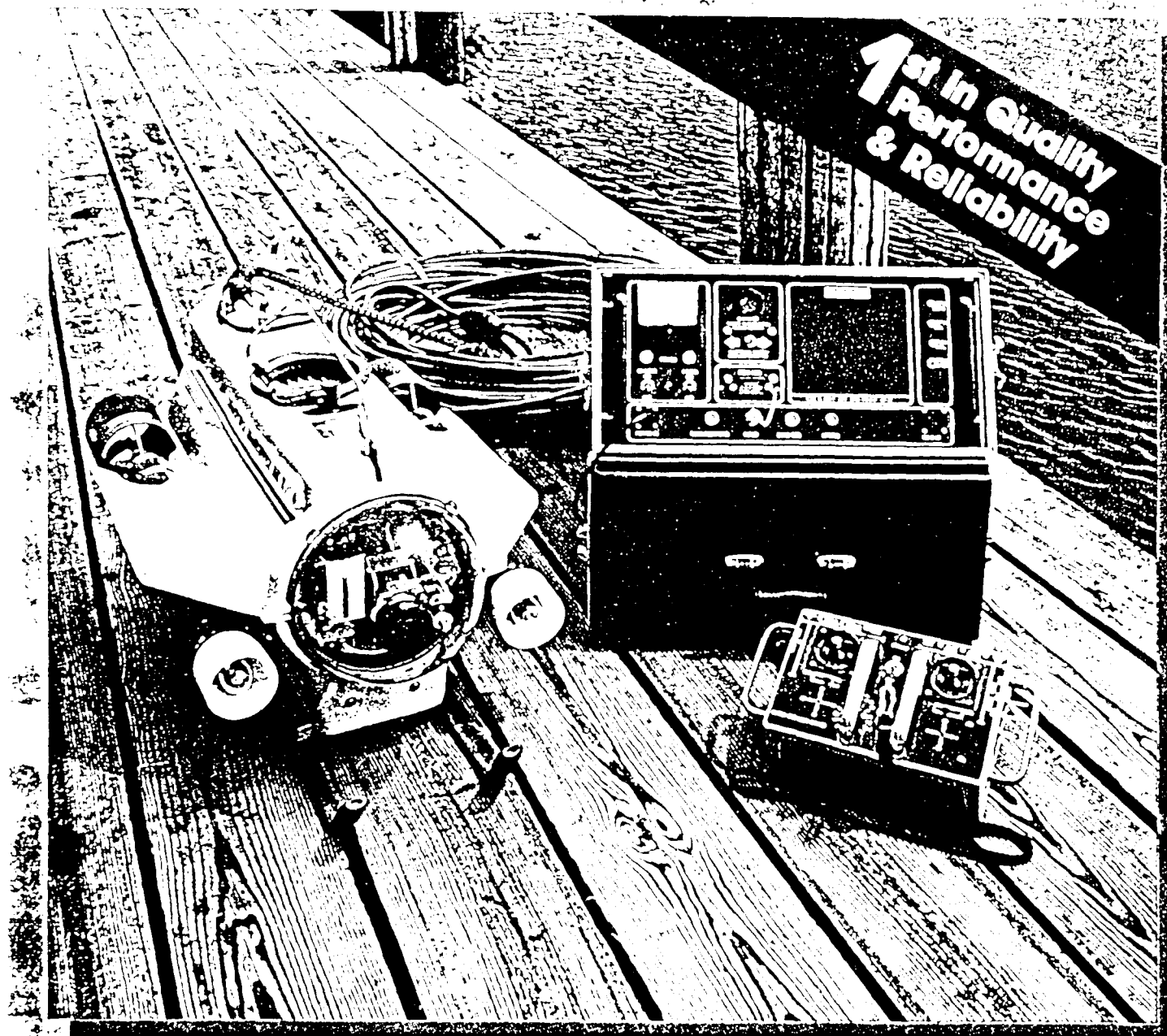
(3) For detecting surface cracking only.

(4) Depends on size of member to be inspected.

(5) Depends on orientation.

APPENDIX B

**1st In Quality  
Performance  
& Reliability**



## **DEEP SEA MiniROVER MK II**

THE MODULAR LC ROV SYSTEM

# MiniROVER MKII The Modular LC ROV System

The MiniROVER MKII is a modular, high performance, upgraded version of the popular MiniROVER MKI. It is designed specifically for the heavy duty needs of commercial and military users. The MKII has greater thrust, speed and depth capabilities than the MKI, yet shares complete commonality of components and spare parts with the original MiniROVER. The MKII can be purchased separately as a system or the standard MKI can be upgraded to MKII specifications at a modest cost.

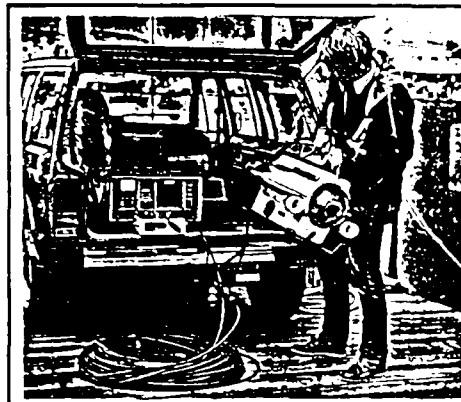
## SYSTEM DESCRIPTION

The MKII is equipped standard with a tilting, low-light level, high resolution, color TV camera. A lateral thruster complements the vertical and high power horizontal thrusters. The 19" rack-mount power console with transit case and a ruggedized hand controller also come as standard equipment. User friendly videographics are an exclusive MKII feature. High accuracy digital depth and heading, date and time, as well as other user required data are displayed

on the pilot's TV monitor. Modular construction allows the user to reconfigure the system to best suit the task at hand.

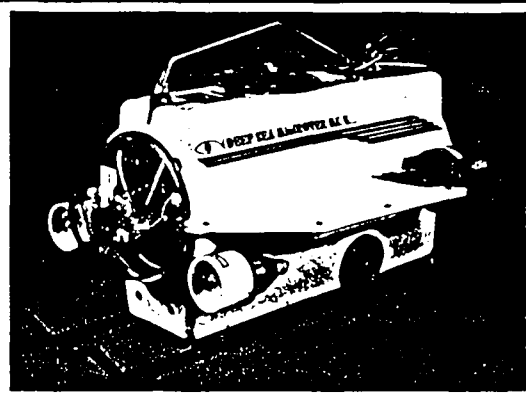
A variety of standard options are available off-the-shelf. The vehicle is equipped with spare UW connectors and has additional AC/DC power available for use as required.

Designed for performance and flexibility once available only in larger, more expensive ROV systems, the MiniROVER MKII is the most cost-effective ROV system in the world.



## SYSTEM HIGHLIGHTS

- Low purchase price
- Minimal operating costs and support requirements
- Compact size and light weight
- Transportable as luggage
- Modular construction
- 10-year spares support program and off-the-shelf delivery of spares



## TECHNICAL SPECIFICATIONS

### GENERAL OUTLINE

<b>VEHICLE</b>	
Operational Depth:	0 to 500 ft. (152 meters) standard 0 to 890 ft. (270 meters) optional
Size	Length 34 in. (86cm) with skids
	Width 18.5 in. (47cm)
	Height 16.5 in. (42cm) with lift bail
Weight	70 lbs. $\pm$ 5 (32 kg) dependent on options
Forward Speed (optional)	2.5 knts in still water (Dual H thruster) 2.9 knts in still water (Quad H thruster) Proven operable in currents up to 1.5 knts
Payload	8 to 12 lbs. (3.6 to 5.4 kg) user adjustable
Buoyancy	$\pm$ 1 lb. (.45kg) in seawater
Stability	Inherent low center of gravity in roll and pitch
Mag and Acoustic Signatures	Mag $\pm$ 28 gamma RMS (ref. 1 meter)
	Acoustic +30 db peak above ambient (ref. 1 meter / 1 micropascal)

### SURFACE POWER UNIT

Size (overall)	Height	9.5 in. (24 cm)
	Width	22 in. (55 cm)
	Length	26 in. (66 cm)
	Weight	61 lbs. (27.8 kg) max. shipweight

### RUGGEDIZED HAND CONTROLLER

Size (overall)	Height	6.5 in. (17 cm)
	Width	12 in. (30 cm)
	Length	6 in. (15 cm)
	Weight	5.0 lbs. (2.28 kg)

### VIEWING SYSTEM

TV Camera:	Low-light, high-resolution color TV camera with 4.8mm / f 1.6 lens NTSC or PAL available
Sensitivity:	1 ft. candle (10 lux) color. .5 ft. candle B/W
Horizontal Resolution:	350 lines typical
S/N Ratio:	46 db typical
Lens Viewing Angle (in water)	Horizontal 86°, $\pm$ 5° Vertical 58°, $\pm$ 5°
TV Tilt	$\pm$ 55° from center, speed of 45° per second Servoed to operators control position
Lights	Two 150 watt long-life quartz halogen lamps with remote On/Off at control console (250 watts optional)

### UMBILICAL CABLE

Length	500 ft. (152 meters) standard, 1500 ft. (456 meters) max. 3000 ft. (912 meters) optional
Weight in Water	13 lbs. per 1000 ft. (5.9 kg per 304 meters)
Strength	850 lbs. (388 kg) breaking
Construction	Outer abrasion jacket of TPR over kevlar strength member, flexible $\pm$ 60°C
One high quality COAX (75 ohms imp) 14 #26 AWG separately insulated conductors, all 600v rated, paired and grouped as required by user with field repairable terminations	

### PROPULSION

Horizontal:	Two thrusters for FWD, REV, CW, CCW movements with 11 lbs. (4.8 kg) min. thrust Continuous (5½ lbs. (2.5 kg) thrust each)
Optional:	Quad Thruster Package providing 20 lbs. of peak thrust continuous min.
Lateral:	One thruster mounted in tunnel under main hull for lateral left/right movements 3 lbs. (1.4 kg) of thrust peak
Vertical:	One thruster, centrally located, mounted in tunnel through main hull 3 lbs. (1.4 kg) of thrust peak with full screens.
All thrusters are proportionally controlled in speed and direction via joysticks on ruggedized hand control box.	

### SUPPORT REQUIREMENTS

Power:	100/120/208/240 VAC $\pm$ 10%, 50/60 Hz 1 kw max.
Crew:	One pilot/technician One pilot/tender
Generator:	1500 watt min. capacity, Recommended with 3½ hr. min. fuel capacity typical
Transport:	Two man portable All components in shipping cases Any suitable vehicle or craft

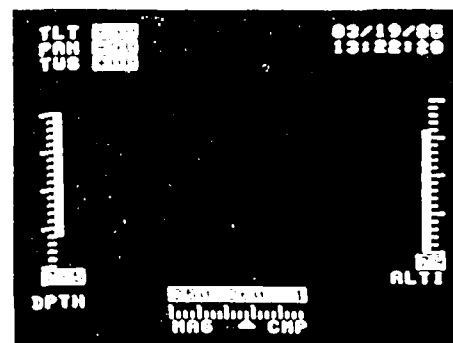
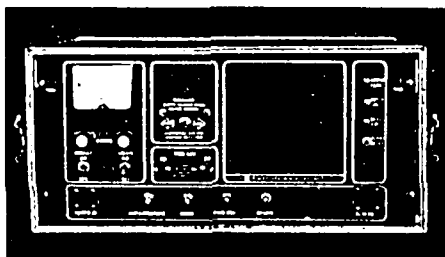


#### HAND CONTROLLER FEATURES

Heavy-duty cast aluminum case  
Joystick and control drop protectors  
User-definable auxiliary functions  
Dual range propulsion controls  
Remote vehicle On/Off control  
25 ft. extension cable

#### CONTROL CONSOLE FEATURES

47 in. x 19 in. x 10 in.  
Modular design  
Isolated safety shut-off timer  
System electrical leakage detector  
Video isolation transformers  
49 in. rack mount chassis with transit case  
Front panel instruments and connectors  
Multinational power standards  
Cable and Hand Controller storage inside bottom cover



#### VIDEOGRAPHICS DATA DISPLAY

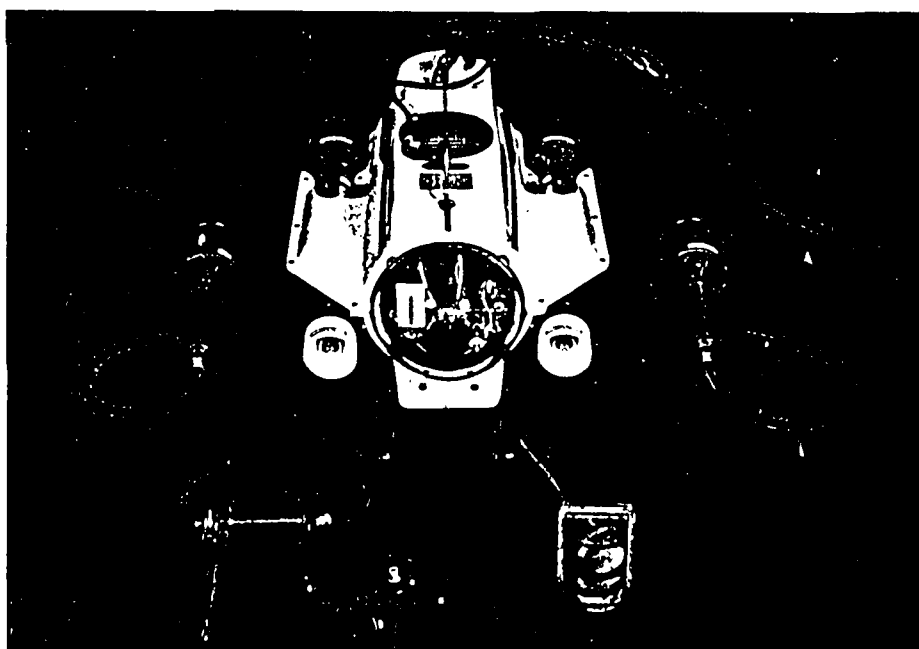
Analog compass rose  
Tether cable turns counter  
Analog depth bar graph  
Data and time with battery back-up  
Relative altitude and depth display  
Pan and tilt camera (optional)  
Dual auxiliary analog inputs (CP, temperature, etc.)  
Front panel controls (calibrations and reset)  
Video enhancer Amp.  
Dual video outputs (video and videographics)

**SIMPLE, BASIC AND RELIABLE.**

#### NAVIGATIONAL AIDS/DATA DISPLAYS

Depth:	Analog strain gauge pressure sensor
Range:	0 to 890 ft. (270 meters)
Display:	3 1/2 digit and analog bar graph
Accuracy:	±0.5%
Resolution:	1 ft. (3 meters)
Heading:	Flux gate magnetic sensor
Range:	0° to 359°
Display:	3 digit and compass rose
Accuracy:	±2.0% max
Resolution:	2° typical

Note: All navigational aids and data are displayed on pilot's TV monitor via user friendly videographics unit.



#### DATA DISPLAY

Date/Time:	Hours, minutes, seconds, day, month, year (bat. back up)
Turns:	±99 count
Ref Depth Sensor:	±50 ft.
Relative:	
Altitude Depth:	Reset on front panel
Aux inputs:	Two analog input channels 0 to 5 VDC (12 bit resolution) Displayed as 4 digit or lower count range

#### VEHICLE FEATURES

Long life, oil filled thrusters  
Quick disconnect tether cable  
Streamlined, impact and foul resistant hard hat covering  
100 ft. 4 kg payload capacity  
Thrust and payload bay  
12 pin electrical connectors and power supply with digital depth and heading sensors  
Two 600 mcd lights

#### MODULAR OPTIONS

Articulator tool package  
Quad horizontal thruster  
35mm photo camera and strobe light  
Panning and tilting color TV camera  
0 to 890 ft. (270 meters) depth rating  
3000 ft. (912 meters) tether cable  
Videographic keyboard  
Videographic remote sensor input  
Scanning sonar (Mesa 971 or UDI AS140)  
High speed towing kit

# MiniROVER MKII

## APPLICATIONS.

The MiniROVER has operated successfully on diverse commercial, scientific and military applications worldwide.

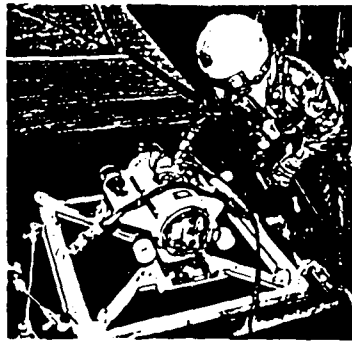
## GENERAL

Under-ice surveys and operations  
In situ biological studies and sampling  
Diver observation and management  
Dam and tunnel inspection  
Interior and external pipeline inspection  
Inspection of nuclear reactor facilities  
Salvage operations  
Offshore structure surveys  
Inspection of sewer and water systems  
Police and rescue squad operations

## MILITARY

Portside security sweeps  
Sonar dome surveys  
Airborne and shipborne MCM Identification  
Damage control and assessment  
Ship and sub-hull security  
as well as many other applications

Consult factory with your requirements



## WORLD LEADER IN LC ROV TECHNOLOGY

### WORLDWIDE SERVICE AND SUPPORT

In U.S.A.: Benthos Inc.  
Edgerton Drive  
North Falmouth, Mass. 02563  
U.S.A.  
Telephone: (617) 540-5500  
Telex: 820673

In Europe: MK Services Ltd.  
Units 5 & 6, Collec Depot  
Billington Road, Leighton Buzzard  
Beds LU7 9HH  
United Kingdom  
Telephone: (44) 525-382333  
Telex: 825654

### CUSTOM-BUILT ROVs

Deep Sea Systems has extensive ROV engineering experience and the manufacturing capacity to custom-design and build any special ROV requirements from the smallest to the deepest (6000m)—for commercial and military applications. Please contact our sales office with your requests.

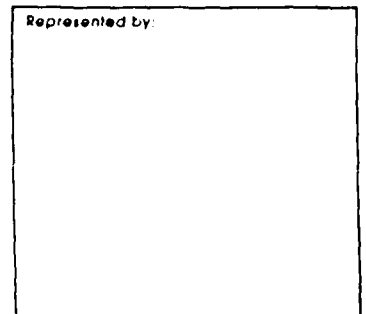


P.O. Box 622, Falmouth, MA 02541 USA  
617-540-6732 Telex: 910 380 7490

### DEEP SEA SYSTEMS INTERNATIONAL, INC.

has an ongoing Product Refinement Program. Specifications are subject to change without notification.

Represented by:



APPENDIX C

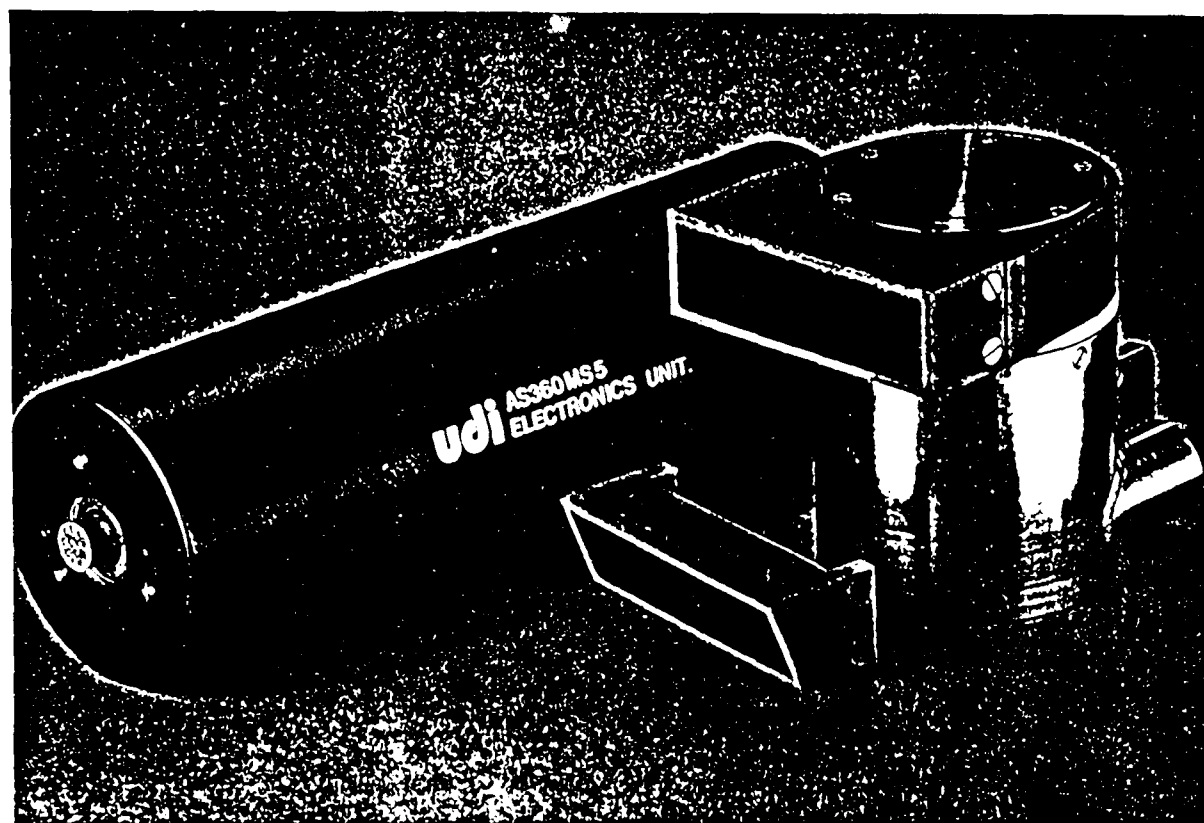
# udi GROUP LIMITED

HIGH RESOLUTION SCANNING SONAR

AS360 MS5

ROV SYSTEM

MODEL 2536



## ROV System

UDI introduce a 3rd generation sonar, AS360 MS5 derived from the highly successful AS360 general purpose sonar.

The AS360 MS5 is a mechanically scanned sonar of high resolution capability specifically designed for installation on small remotely operated unmanned vehicles. With a range of up to 60 metres the search capability is extended beyond that achieved by television. At shorter ranges the combination of modern TV refreshed techniques and wide sonar bandwidths offer the operator the optimum in visual presentation in both monochrome and colour.

Frontal area has been minimised by the use of an independent scanning head and separate external electronics unit. This ensures low drag and allows the sonar and electronics to be placed in the optimum positions on the ROV for both balance and hydrodynamic.

Utilising state of the art microprocessor techniques minimises the conductor requirement to a screened twisted pair (power obtained from vehicle) and gives high immunity to electrical noise, ensuring good operational reliability over a wide variety of umbilical configurations and lengths.

## UDI Group Ltd.

UDI is part of John Brown Engineers and Constructors who are a wholly owned Subsidiary of Trafalgar House PLC dedicated to development in the field of Subsea Technology. The Company supplies high resolution sonar and television to the offshore and military markets. Engineering activities include the development and operation of Subsea work systems such as the Trenching and Cable Burial System.

Operations also include a survey division with considerable experience in offshore positioning, navigation and sonar surveys.

Underwater Systems

**JOHN BROWN**

# HIGH RESOLUTION SCANNING SONAR

AS360 MS5

## ROV SYSTEM

MODEL 2536

### SYSTEM DESCRIPTION

#### Transducer Unit

Model No. 2350

A pressure compensated unit housing the transducer drive motor, preamplifier, and angle sensor connected to the electronics unit by a 3 metre fluid filled cable assembly. The transducer array is interchangeable to allow user flexibility (optional transducers available).

#### Electronics Unit

Model No. 2352

The circuits for control and operation of the transducer are mounted in a one atmosphere hard anodised aluminium housing. Integral power supplies enable system operation from a single 24 volt DC supply.

#### Interconnection Cable

Model No. 2255

A 10 metre polyurethane 6 way cable for interconnecting the Electronics unit to the Surface Control unit. Used for test and service purposes. A 2 metre cable whip (Model 2255 - 2001) terminated with electronics unit connector only is supplied for client termination to vehicle umbilical.

#### Control Unit

Model No. 2027

Built in a standard 19 inch rack chassis - full control of scanning functions (sector direction, size, etc.) are available to the operator. A single gain control (time and RGC Laws being programmed internally) ensures simplicity of setting.

Separate video outputs of high resolution RGB/composite colour and monochrome allow both to be displayed simultaneously or recorded on standard video machines.

Self-testing software routines provide early warning of potential system failure.

Unit is provided in a splashproof transit enclosure.

### OPTIONS

See options sheet for description of units.

Option	Part Number
Stand Alone Monochrome Display	2081
19" Rack Mount Monochrome Display	2085
Stand Alone Colour Display	2088
Integral Enclosure (Surface Unit and 19" display)	2089
Multi-target Marking Cursor Control Unit	2071
Multi-target Page Store	2027 - 3010

### SPECIFICATION

#### Transducer Unit

Frequency	700 kHz
Beam Width	Transmit 15° x 50°
Beam Width	Receive 15° x 50°
Height	137mm
Diameter	88mm
Weight in Air	2.3 Kg
Weight in Water	1.4 Kg
Material	Nylatron
Depth Rating	750 metres

All specifications and information are based on current data at the time of publication approval. UDI reserve the right without notification or obligation to change, modify and update designs and specifications as part of their ongoing product improvement programme January 1987.

#### Interconnecting Cable

10 metre 6 way 15mm O/D polyurethane sheathed

#### Electronics

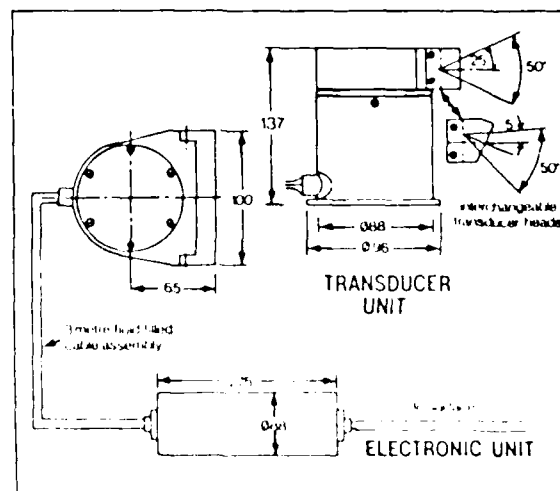
Length	275mm
Diameter	88mm
Weight in Air	2.4 Kg
Weight in Water	0.6 Kg
Connector	Umbilical 6 way male UDI Transducer 12 way female UDI
Material	Hard anodised aluminium
Depth Rating	750 metres
Power Supply	22 - 27 volts DC 24VA
Telemetry	RS422 ± 62.5 KBIT/SEC

#### Umbilical Requirements

Conductors	2 (screened twisted pair - recommended)
Max acceptable Cable loss	40db at (0 to 16MHz)
Max Cable loop resistance	130 ohms
Max Cable length using RG108	1600 metres

#### Control Unit

Ranges	10, 20, 40, 60 m
Sector Sizes	15° 30° 60° 90° 160° 270°
Sector Position	Adjustable
Gain	Automatic or Manual
Display Modes	Scan or Flyback
Video O/P (Mono)	Composite Video
Video O/P (Colour)	R.G.B. plus Sync (composite video)
Power Supply	240/110V ac 200VA (Auto Selecting)
Temp Operating	0°C to +40°C
Temp Storage	-20°C to +60°C
Weight	25Kg
Dimensions	549(W) x 202(H) x 342(D)
Construction	19 inch Rack fitted in splashproof enclosure



**UDI GROUP LIMITED**

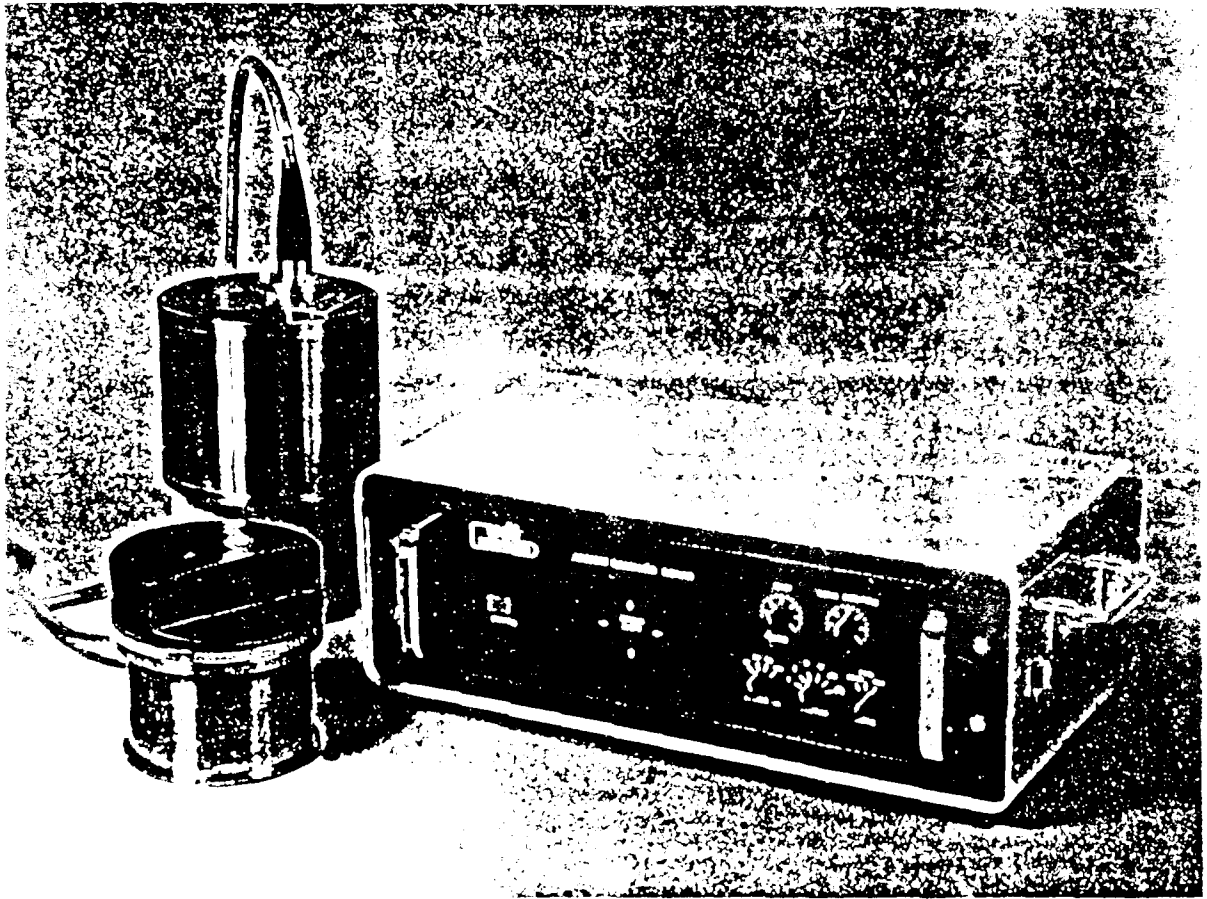
Denmore Road  
Bridge of Don  
Aberdeen AB2 8JW

Telephone: (0224) 703551 Telex: 73361 Fax: 8213

Underwater Systems

**JOHN BROWN**

# udi GROUP LIMITED



# HIGH RESOLUTION SCANNING SONAR AS360 MS1A

## ROV SYSTEM MODEL 2534

### SYSTEM DESCRIPTION

#### Transducer Unit Model No. 2340

A mechanically scanned Transducer array manufactured in UPVC with the motor drive mechanism and pre-amplifier electronics housed in a one atmosphere titanium alloy body permitting a depth capability to 1500 metres

#### Electronic Unit Model No. 2332

The electronics are mounted within a titanium alloy housing ensuring the maximum immunity from corrosion and allowing a depth capability to 1500 metres.

#### Transducer Cable Model No. 2254

A 3 metre polyurethane 12 way cable for interconnecting the Transducer unit and the Electronics unit.

#### Interconnection Cable Model No. 2249

A 10 metre polyurethane 3 way cable for interconnecting the Electronics unit to the Surface Control unit. Used for test and service purposes. A 2 metre cable whip (model 2249 - 2001) terminated with electronics unit connector only is supplied for client termination to vehicle umbilical.

#### Control Unit Model No. 2027

Built in a standard 19 inch rack chassis - full control of scanning functions (sector direction, size, etc) are available to the operator. A single gain control (time and RGC laws being programmed internally) ensures simplicity of setting.

Separate video outputs of high resolution RGB/composite colour and monochrome allow both to be displayed simultaneously or recorded on standard video machines.

Self-testing software routines provide early warning of potential system failure.

Unit is provided in a splashproof transit enclosure.

### OPTIONS

See options sheet for description of units.

Option	Part Number
Stand Alone Monochrome Display	2081
19" Rack Mount Monochrome Display	2085
Stand Alone Colour Display	2088
Integral Enclosure (Surface Unit and 19" Display)	2089
Multitarget Marking Cursor Control Unit	2071
Multitarget Page Store	2027 - 3010

### SPECIFICATION

#### Transducer Unit

Frequency	: 500kHz
Beamwidth	: Transmit 1.4° x 27°
Beamwidth	: Receive 3.4° x 27°
Pulse Width	: 100 us
Angular Scan Rate	: 18°/sec, 18°/sec, 12°/sec, 7.2°/sec (Range dependant)
Height	: 155mm
Diameter	: 155mm
Weight in Air	: 5.15Kg
Weight in Water	: 2.9Kg
Material (Body)	: Titanium Alloy
Material (Transducer)	: UPVC
Depth Rating	: 1500 metres

All specifications and information are based on current data at the time of publication approval. UDI reserve the right without notification or obligation to change, modify and update designs and specifications as part of their ongoing product improvement programme January 1987

#### UDI GROUP LIMITED

Denmore Road  
Bridge of Don  
Aberdeen AB2 8JW

Telephone (0224) 703551 Telex 73361 Fax 821339

#### Interconnecting Cables

3 metre 12 way 14mm O/D Polyurethane Sheathed  
10 metre 3 way 11mm O/D Polyurethane Sheathed

#### Electronic Housing

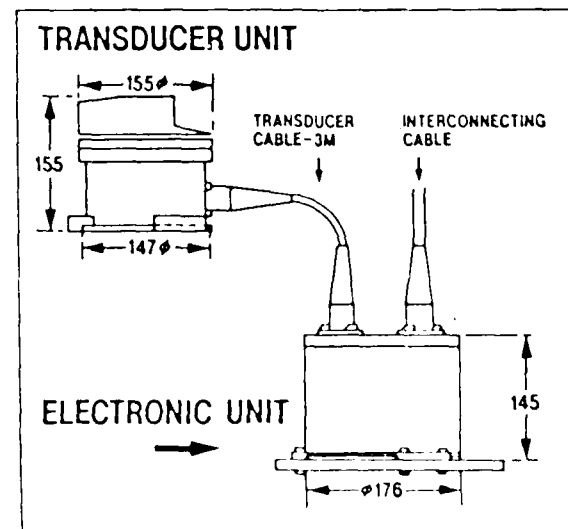
Diameter	: 176mm
Height	: 145mm
Material	: Titanium Alloy
Depth Rating	: 1500 metres
Weight in Air	: 6Kg
Weight in Water	: 2.5Kg
Communication	: Bi-directional FSK telemetry link

#### Umbilical Requirements

Conductors	: 2 (Screened Twisted Pair preferred)
Max acceptable Cable loss	: 40db at (0.5 to 1.6MHz)
Max Cable loop resistance	: 130 ohms
Max Cable length using RG108	: 1.6Km

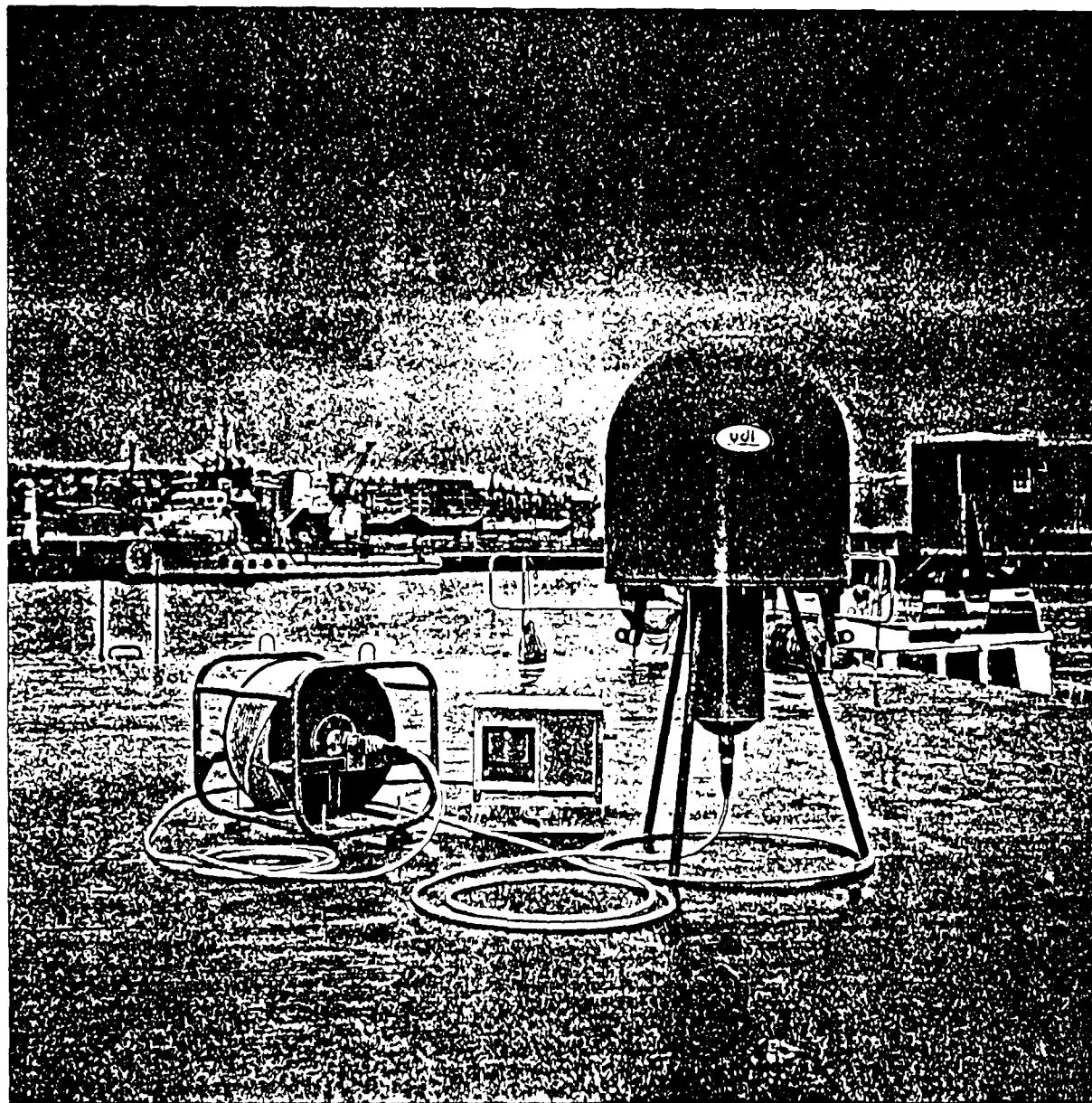
#### Control Unit

Ranges	: 10, 20, 40, 100m
Sector Sizes	: 15°, 30°, 60°, 90°, 180°, 270°
Sector Position	: Adjustable
Scanning Modes	: Continuous or Sector
Gain	: Automatic or Manual
Display Modes	: PPI or Sector
Video O/P (Mono)	: Composite Video
Video O/P (Colour)	: RGB plus Sync (composite video)
Video O/P Format	: PAL or NTSC
Power Supply	: 240/110V ac selectable 200VA
Temp Operating	: 0°C to +40°C
Temp Storage	: -20°C to +60°C
Weight	: 25Kg
Dimensions	: 549(W) x 202(H) x 342(D)mm
Construction	: 19 inch Rack fitted in splashproof enclosure



Underwater Systems

JOHN BROWN



The AS370 Seabed Surveillance Sonar complements a family of mechanically scanned sonars specifically designed for security and underwater surveillance systems. This family comprises the AS360, AS370 and AS380.

The AS370 is designed with long term immersion capabilities for coastal waters and harbour surveillance installations, where protection against underwater intruders such as divers, submersibles or offensive underwater craft is required.

The capability of connection of several underwater sensors controlled by a single operator surface unit exists providing a reduction in overall cost and complexity of multiple systems.

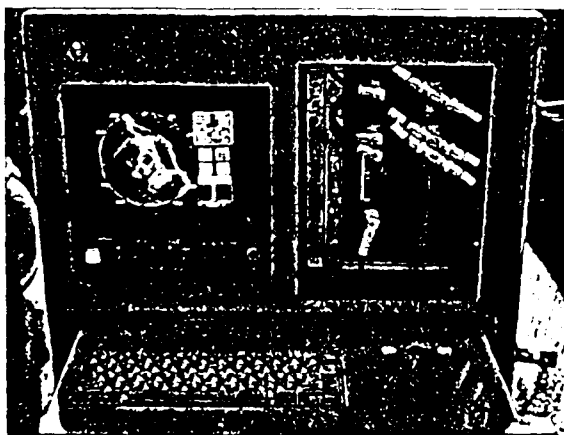
Integration to larger systems is readily accomplished via standard computer interfaces.

# SEABED SURVEILLANCE SONAR

# MODEL AS370

The AS370 surveillance sonar is designed to meet the following operational criteria.

- Long Term Underwater Immersion
- Shallow Water Deployment
- Ranges to 1000m
- High Resolution Display
- Secure Long Interconnection
- Immunity to Acoustic Interference



CONTROL UNIT

## Control Unit:

The surface control unit offers various display and processing features. These include:

- Six Page Storage and Recall
- Zoom x 5 Magnification
- Origin Shift x 2 Magnification
- Normal PPI Display
- Recordable Video Output Format

The keyboard allows further reference annotation to be made on the screen.

## Control Modes:

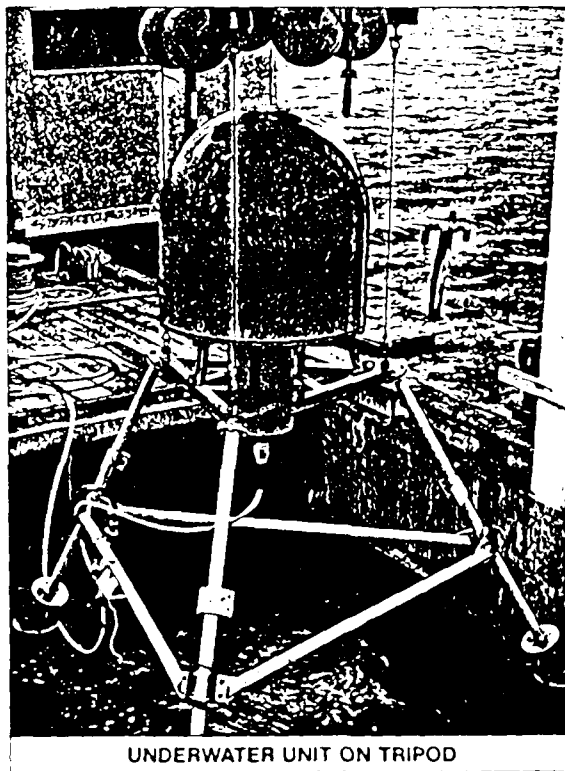
The following control modes are available to the operator accessed via ICONS

- Gain Law
- Transmission Power
- Scan Position
- Compass Correction
- Range
- Alarm Functions
- Beam Tilt
- Sonar Modes
- Zoom

## Sonar Modes:

There are three sonar modes employing different transmission and signal processing techniques. These are:

- PCW : For optimum range resolution
- CHIRP : For maximum interference immunity
- DOPPLER : Target relocating analysis



UNDERWATER UNIT ON TRIPOD

## Alarm Facilities:

Enables the detection and tracking of sonar targets which satisfy selectable predetermined parameters such as:

- Amplitude/ Threshold
- Target Size
- Doppler Content

By selection, the operator may be presented with either:

- Alarm Contacts Only
- Sonar Plus Alarm Contacts

Noisance alarm triggering may be eliminated whilst using high sensitivities by means of a paint box facility.

### Systemisation Features:

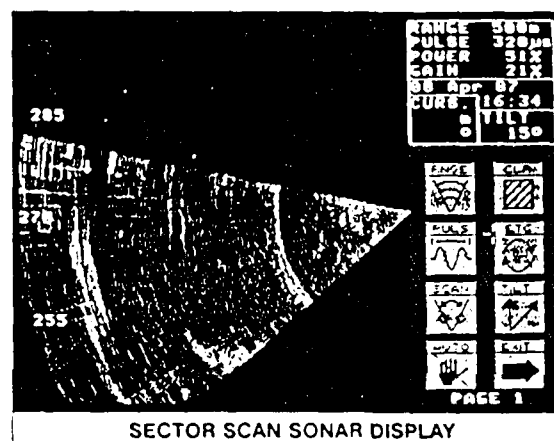
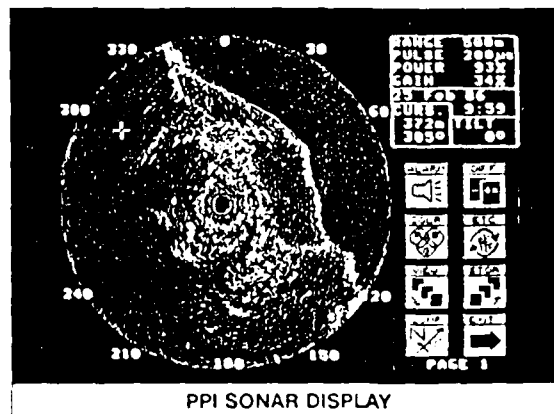
**Multiple Underwater Units** – For installations requiring extensive underwater coverage a number of underwater units may be controlled by a single surface unit.

### Complete System Integration:

By use of standard computer interfaces, the AS370 surface control unit may be controlled remotely allowing integration into larger surveillance systems.

### Mechanical Construction:

The transducer array rotates within an acoustically transparent GRP dome which prevents marine growth forming on sensitive array surfaces. All components exposed to seawater are manufactured in GRP, PVC or stainless steel material. As an additional precaution, the dome can be filled with clear, fresh water prior to final seabed installation.

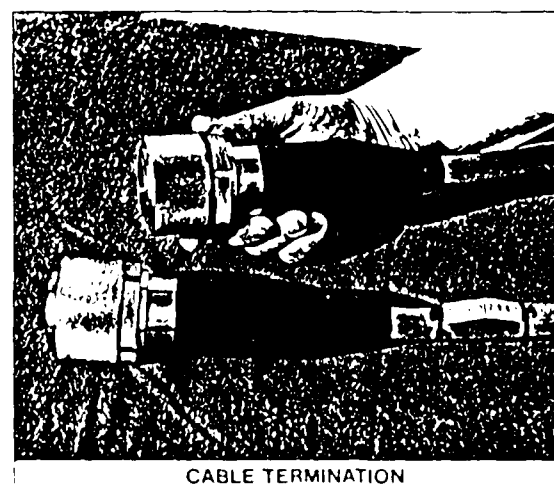


### Cable:

The interconnecting cable is constructed with combined electrical and optical fibre conductors supported by a Kevlar stressmember and finished in an outer jacket of polyurethane. Cable is terminated in a strain bearing connector to suit customer length requirements. Single cable lengths of up to 6Km may be used. However, this can be increased by means of inline signal repeaters.

### Cable Handling Equipment:

A slip ring hand winch is available on request for site test work purposes. Also storage reels to facilitate site installation work.



# SEABED SURVEILLANCE SONAR

MODEL AS370

## SPECIFICATION:

### Sonar

Beampattern : 4° x 6°  
 Range : 50, 100, 200, 500, 1000m.  
 Transmission Power : Variable.  
 Scan : Sector or Continuous  
 Transmission Pulse : Variable.  
 Gain Law : Variable or Auto.  
 Beam Tilt : ±15°  
 Sonar Transmission Modes : PCM, CHIRP, DOPPLER.

### Display

RGB : Colour Monitor.  
 PPI : North Corrected Display.  
 Control : Tracker Ball, Icon and Menu.  
 Features : Target Zoom.  
 : Intruder Alarm.  
 : Range and Bearing Cursor.  
 : Recordable TV Format.  
 : Alarm Thresholds Variable.  
 : Alarm Inhibit any area on screen.

### Physical

#### Underwater Unit

Depth Rating : 60m.  
 Height : 1900mm  
 Diameter : 1049mm.  
 Weight : 155kg.

#### Display Unit

Dimensions : 575mm wide x 475mm high  
 x 515mm deep.  
 Weight : 56kg  
 Power : 220-240V, 50/60Hz 500VA  
 Cable : Combined electrical/Fibre  
 optic with Kevlar Stress  
 member.  
 Weight : 40Kg/100m.

## UDI Group Ltd

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All specifications and information are based on current data at the time of publication approval. UDI reserve the right without limitation, investigation, to change, modify and update designs and specifications as part of their ongoing product improvement programme.  
 May 1987

## udi GROUP LIMITED

Denmore Road  
 Bridge of Don  
 Aberdeen AB2 8JW

Telephone: 0224 703551 Telex: 73361 Fax: 821339

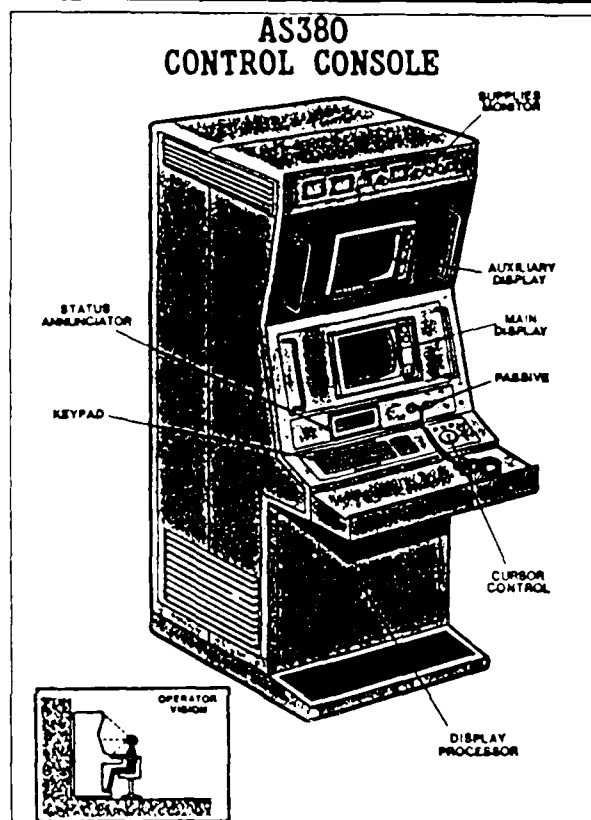
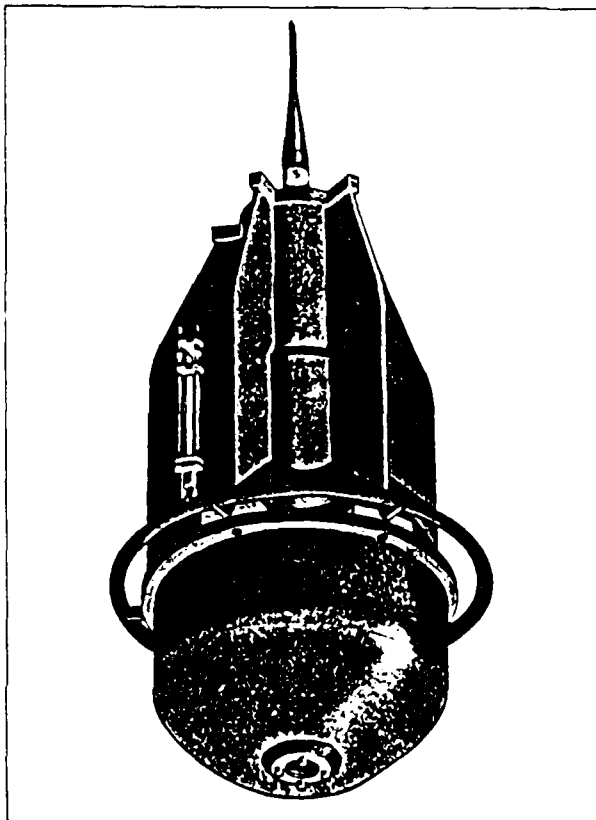
Life Wave Systems  
**JOHN BROWN**

# udi GROUP LIMITED

## SONAR SYSTEM

AS380

## MULTI-ROLE SURVEILLANCE



### Introduction

The AS380 is a sophisticated multi-role surveillance system designed for either permanent installation or mobile deployment. The system comprises an underwater unit with rotating multiple-array transducer assembly and a single operator controlled console. State of the Art electronics and signal processing techniques plus the latest ideas for operator control are combined in the AS380 to give an extremely versatile system which is simple to use and requires minimum operator training. The extensive control and monitoring facilities enable the sonar performance to be optimised to suit any medium/long range surveillance requirements within the scope of the system.

Two basic scan modes are available — detection mode and classification mode. In the detection mode the system can perform a comparatively fast general purpose search for stationary or moving targets up to 3Km away.

The classification mode enables further, more detailed, analysis of targets within a range of 1Km. The system can also operate in a 'listen only' passive mode if required allowing a bearing estimation of audible man-man noise within the vicinity.

Further sub-modes such as bathymetric profiling including speed of sound, depth, temperature and height measurements are included.

### Typical Applications

- Submarine Detection
- Harbour Protection
- Intruder Detection (Divers)
- Oil Platform Security
- Salvage Operations

### Mobile Deployment

The AS380 underwater unit may be deployed from a ship or helicopter to provide a mobile search facility. The unit is lowered into the water by its umbilical from a hand or electric slip ring winch. To prevent contact of the underwater unit with the seabed, an echo sounder provides an audible warning and altitude measurements at heights of less than 30m. Depth, temperature and sound velocity measurements are also continuously displayed.

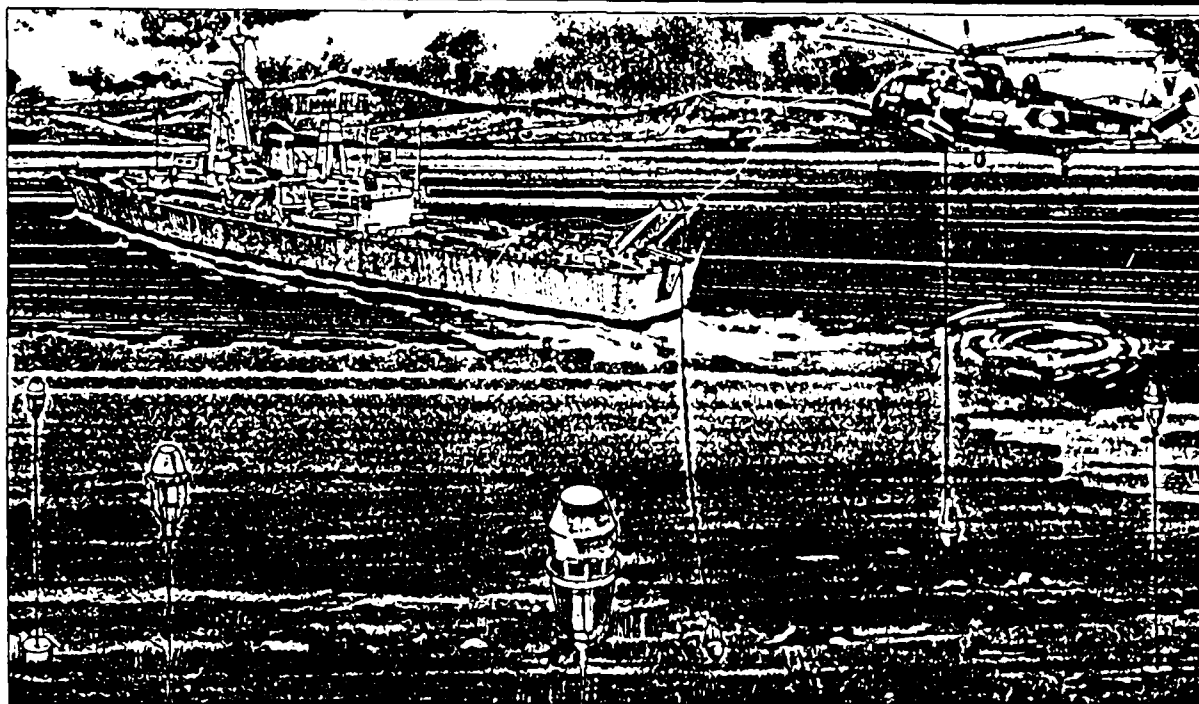
### Permanent Deployment

For permanent installation the underwater unit is fitted with a subsea buoy and moored to a seabed fixture via its umbilical. The control console can be left unmanned while the system 'looks' for intruders. An alarm is automatically raised if an intruder is detected. Alternatively the many facilities of the system enable more careful manned monitoring of the scene.

### UDI Group Ltd

UDI is part of the worldwide Engineering Group of John Brown PLC dedicated to development in the field of Subsea Technology. The Company supplies high resolution sonar and television to the offshore and military markets. Engineering activities include the development and operation of Subsea work systems such as the towline trenching and cable laying system. Operations also include a survey division with considerable experience in offshore positioning, navigation and sonar surveys.

# AS 380 DEPLOYMENT METHODS



## Control Console

	Shipboard/Seabed Deployment	Helicopter Deployment
Construction	Single Operator Console	Single Operator Console in open frame construction
Dimensions	1770 x 750 x 990	
Weight	150Kg	
Monitors	RGB 750 line resolution	RGB 750 line resolution

## Specification

### ACOUSTIC

#### Detection Mode:

Frequency	50kHz
Beam pattern	Horizontal 30° Vertical 10°
Modulation	FM (Chirp) CW (Doppler)
Pulse Width	Variable
Sector Coverage	Any 60° in 360° or 360° continuous
Range	1000/2000/3000m

#### Classification Mode:

Frequency	50kHz
Beam pattern	Horizontal 3° Vertical 20°/30°/60°
Sector Size	Variable
Range	250/500/1000
Zoom Factor	x 5
Passive Mode	Audio Band
Sensor	Depth/Temperature/Altitude/Tilt/Compass/Speed of Sound

## Underwater Units

Depth Rating	60m	250m
Temperature	-10 to +40°C	-10 to +40°C
Helicopter Deployment	110Kg*	180Kg*
Ship Deployment	120Kg*	200Kg*
Dimensions	1520 x 720mm	1520 x 720mm

\*All weights quoted are in air

## Features

Detection Mode	360° coverage Chirp and Doppler Doppler filtering
Classification Mode	Target Scanning Zoom Increased range resolution
Passive Mode	High sensitivity Bearing
Bathymetric Mode	Velocity/Temperature/Depth/Altitude
Additional Features	Optimisation of receiver gain and transmitted sonar parameters Compass compensated PPI display Tilt and water leak sensors System and umbilical integrity monitoring
Control Features	System control is fully programmable and is presented to the operator via display ICONs and menus. Control is achieved either by keyboard or cursor implementation

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Denmore Road  
Bridge of Don

Underwater Systems



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# HIGH RESOLUTION SCANNING SONAR

MTM

## MULTI-TARGET MARKING SYSTEM

MODEL 2071

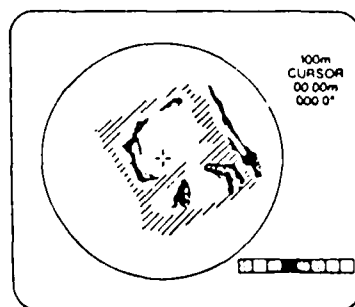
### CURSOR CONTROL UNIT, SPECIFICATIONS

Parameters	Specification
<b>Dimensions</b>	
Operational	: 216 (L) x 121 (W) x 76mm (H)
<b>Weight</b>	
Operational	: 1.4kg
<b>Inputs</b>	
Power Supply	: 5V dc
<b>Outputs</b>	
Control Signals	: TTL levels (see section 4)
Connector	: 9 way 'D' type
Cable	: 8 core screened
<b>Operator Controls</b>	
Cursor pushbutton:	Enables cursor and text display
Store pushbutton:	Stores current sonar and text display
Review pushbutton:	Recalls any one of four previous sonar and text displays
Trackerball	: Moves cursor
Display Cursor	: '+' moved by trackerball

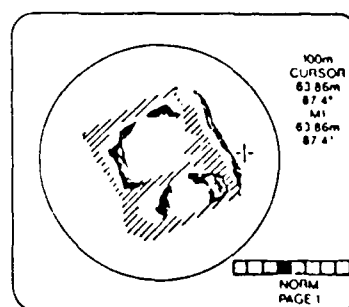
Marker (Single Mode)	: 'X' set by cursor pushbutton
Marker (Multiple Mode)	: Up to five numbered markers set by cursor pushbutton on each of the four displays
Text	: Cursor and marker distance and bearing measurements
Display Resolution:	Resolution is the same for both European and American formats. The following figures assume the origin is shifted.
Range:	Resolution:
100m	0.45m
40m	0.18m
20m	0.09m
10m	0.05m

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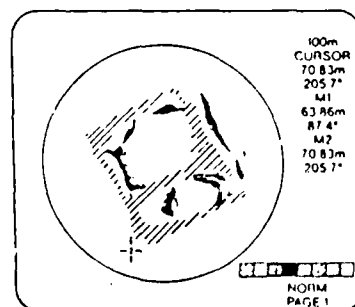
January 1987



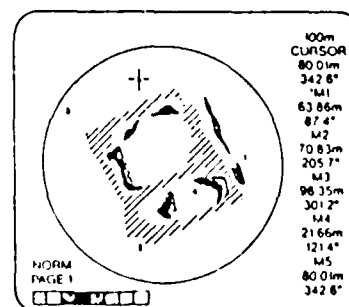
CURSOR AT CENTRE



CURSOR & MARKER 1 AT 63.86m



NORM PAGE 1



NORM PAGE 1

Sequence of events using 5 markers

**UDI GROUP LIMITED**

Denmore Road  
Bridge of Don  
Aberdeen AB2 8JW

Telephone: (0224) 703551 Telex: 72361 Fax: 821339

Underwater Systems

**JOHN BROWN**

# udi GROUP LIMITED

## HIGH RESOLUTION SCANNING SONAR

### AS360 M-SERIES

### OPTIONS

Option	Part No.	Sonar Systems		
		AS360 M	AS360 MS1(A)	AS360 MS5
Stand Alone Monochrome Display	2081	Yes	Yes	Yes
19" Rack Mount Monochrome Display	2085	Yes	Yes	Yes
Stand Alone Colour Display	2088	Yes	Yes	Yes
Integral Enclosure (Surface Unit & 19" Display)	2089	Yes	Yes	Yes
Multitarget Marking Cursor Control Unit	2071	Yes	Yes	Yes
Multitarget Page Store	2027 - 3010	Yes	Yes	Yes
Heading Sensor	2370	Yes	Special*	No
200 metre Cable Assembly	2421	Yes	Special*	Special*
Transducer Sealing Hood	2331 - 1007	Yes	No	No
Alternative Underwater Housings		Yes	Yes	No

Future Release				
RS232 Data Interface		Yes	Yes	Yes
IEEE488 Data Interface		Yes	Yes	No
High Resolution Graphics Display		Yes	Yes	No

\* Contact UDI

#### Options

UDI now offer the above options to compliment and extend the versatility of the AS360 M-series of high resolution scanning sonars.

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# HIGH RESOLUTION SCANNING SONAR

## AS360 M-SERIES

## OPTIONS

### Stand Alone Monochrome Display Part No. 2081

A high resolution 9 inch black and white monitor housed in a rugged aluminium splashproof enclosure. The monitor provides the optimum display to match the sonar performance.

All connections are accessed via a front panel and features include a contrast enhancement filter.

Power Supply : 110/240V AC Auto Voltage Select  
Dimensions : 410(W) x 335(H) x 485(D)mm  
Weight : 23Kg

### 19 inch Monochrome Display Part No. 2085

Same as above but configured for 19 inch rack mounting.

Power Supply : 110/240V AC Auto Voltage Select  
Dimensions : 483(W) x 266(H) x 425(D)mm  
Weight : 14Kg

### Stand Alone Colour Display Part No. 2088

A high resolution 13 inch RGB/Composite colour video monitor housed in a rugged aluminium splashproof enclosure with all input and output connections accessed via a front panel.

The high bandwidth of the monitor is matched to the sonar performance and provides optimum display of the colour RGB sonar information.

*Features include monitor auto selection of composite video (PAL/NTSC) inputs.*

Power Supply : 110/240V AC Auto Voltage Select  
Dimensions : 570(W) x 465(H) x 520(D)mm  
Weight : 36Kg

(Display can be supplied with a standard 19 inch rack mount).

### Integral Enclosure Part No. 2089

Housing the high resolution 13 inch RGB/Composite colour video monitor (as above) and surface control unit model the integral enclosure provides an "all in one" surface control and display operating station. Built in a rugged aluminium splashproof enclosure all input and output connections with accessed via a front panel.

Power Supply : 110/240V AC Auto Voltage Select  
Dimensions : 570(W) x 600(H) x 603(D)mm  
Weight : 64.5Kg

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February 1987.

### Multi Target Marking Cursor Control Unit

Part No. 2071

A multi target marking system providing accurate range and bearing measurements of displayed sonar targets. Two modes of operation allow for the measurement to a cursor and up to five marked targets from the sonar or alternatively the relative range and bearing between two targets. The cursor control unit enables the display and movement on screen of a cursor. The position of the cursor and subsequent marked positions appear as range and bearing information on screen and to the right of the sonar picture.

\* four targets if heading sensor installed.

### Multi Target Page Store Part No. 2072 - 3010

Used in conjunction with Model 2071 (as above) additional display memory enables up to four separate pages of sonar information to be stored and reviewed.

### Heading Sensor

Part No. 2370

A magnetic fluxgate heading sensor provides compass information which after transmission is displayed on screen as either "text" only, "North up" corrected display mode only or "text" and "North up" display mode combined.

### Interconnect Cable Assembly Part No. 2421

For the interconnection of the underwater unit to the surface control unit. The assembly comprises of 200 metres of cable on storage reel and a 20 metre deck cable.

The assembly is used for all general purpose applications where ROV umbilical integration is not required.

### Transducer Sealing Hood Part No. 2331 - 1007

A sealing hood assembly housing the rotating transducer array in a clean fluid medium. For use in severe operating conditions to eliminate the ingress of suspended silt or fine abrasive particles.

### Underwater Housing

Alternative underwater housings are available to meet customer specifications.

**udi** GROUP LIMITED

Denmore Road  
Bridge of Don  
Aberdeen AB2 8JW

Telephone (0224) 703551 Telex 73361 Fax 821339

Underwater Systems

**JOHN BROWN**

APPENDIX D

KLEIN SIMULTANEOUS 100 kHz/500 kHz  
DUAL FREQUENCY TOWFISH - MODEL 422S-101HF

The Klein Model 422S-101HF is the most advanced towfish in the industry. It provides digitally controlled, simultaneous operation of both 100 kHz and 500 kHz side scan sonars, yet retains the physical characteristics of the current single frequency towfish. The towfish contains dual array transducers which send out high intensity 100 kHz and 500 kHz bursts of acoustic energy in fan shaped beams to either side of a moving vessel. The beams are narrow in the horizontal plane and wide in the vertical plane. The nose of the fish is an O-Ring sealed pressure housing which contains the transmitting, receiving and communications switching circuitry. The transmitters energize the transducers when a trigger pulse is received from the shipboard recorder or transceiver. The "State-Of-The-Art" low noise receiving circuits amplify the received echoes and send them up the tow cable to the recorder. The communications/switching board receives digital signals from the surface recorder allowing full operational control of all transmitters and receiving circuitry in the towfish. Klein towfish feature completely modular construction.

## FEATURES:

—Fully compatible with all existing Klein Side Scan Sonar Systems.

--Proven Deep Tow Capability

All Klein Side Scan Sonar Towfish are rated to depths of 1000 Meters. Deep operation has been proven in successful missions by the U. S. Navy and others. Klein Towfish are also available rated to full ocean depth (12,000 meters). Please contact us for details.

—Streamlined

Klein Towfish feature clean hydrodynamic construction for minimum drag and stability at all speeds.

—No Crosstalk

Special construction and electronic techniques help eliminate back radiation and coupling so that one channel does not pick up signal from the other channel.

—Self-Contained Electronics

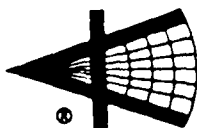
Built in transducer drivers and amplifiers (on easily accessible, replaceable plug-in circuit boards) minimize the effects of cable loading on the signal output and help eliminate the effects of shipboard noise sources. No special tuning is required if the cable length is altered.

—Breakaway Tail

Klein Towfish have stabilizing tail fins which are designed to break away in the event of a snag. Standard fins are flat (Model 14100001) and a circular tail shroud is available as an option (Model 402-403--Standard on Towfish Model 422S-101EF)

--Rugged Construction

Klein standard Model 422S Towfish are constructed of solid, precision machined 316 stainless steel (including hardware) for extreme durability and corrosion resistance. No castings or thin sheet metal are used.



**KLEIN ASSOCIATES, INC.**  
**UNDERSEA SEARCH AND SURVEY**  
Klein Drive, Salem, New Hampshire 03079 • USA  
Phone: 603-893-6131 Telex: 94-7439 Cable: SONAR

## CONFIDENTIAL

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—Fully Modular

Klein Towfish feature easily replaceable transducers. The entire Towfish is fully modular so that any part (including the tow point connections) may be easily replaced in case of damage or wear. Individual towfish modules may easily be mounted on manned or unmanned submersibles.

--Safety Attachment Points

Attachment points are provided in the rear and nose of the Towfish for various kinds of safety rigging.

—Testing

Every Klein Towfish is run in for a minimum of eight hours and then tested and calibrated in our large acoustic test tank.

OPTIONAL FEATURES:

--K-Wing® Built-In Depressor

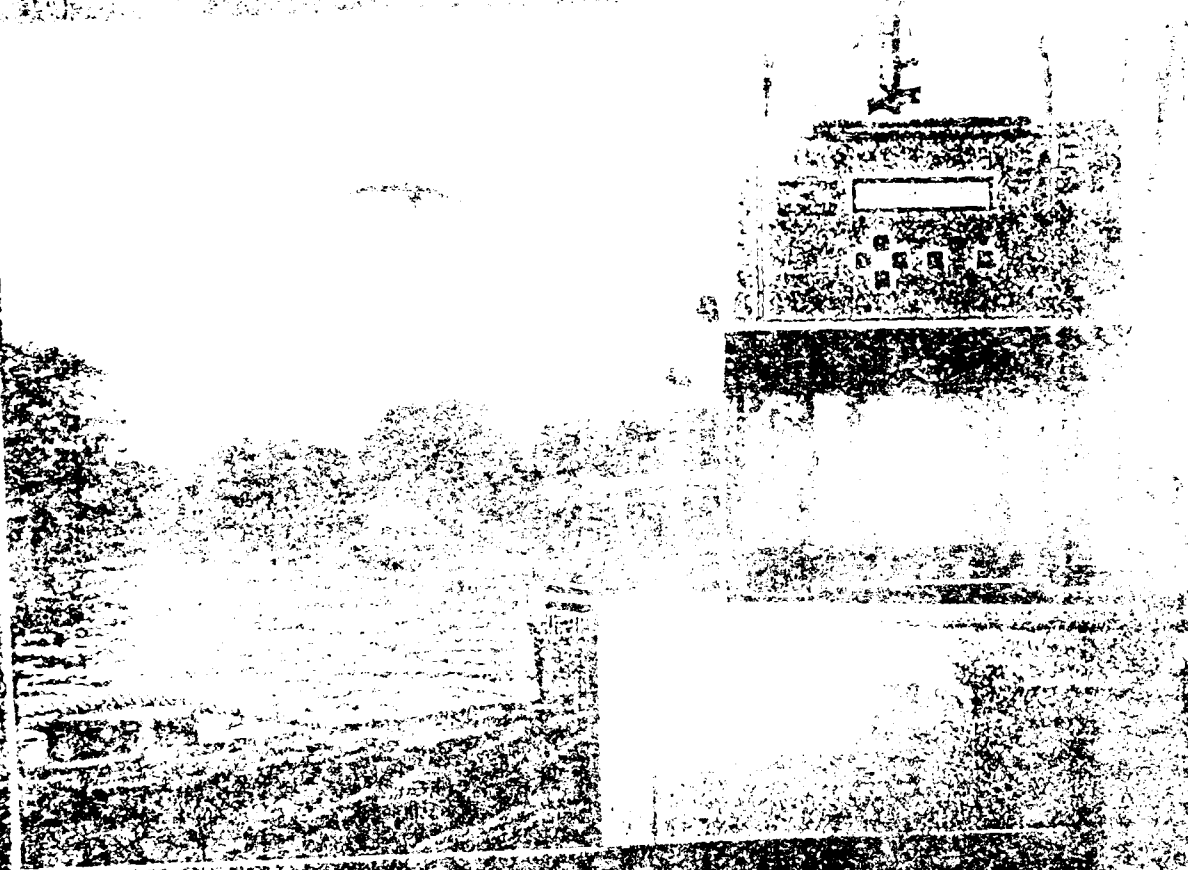
The Klein K-Wing® I and K-Wing® II Depressors attach directly to the Towfish. The K-Wings® help improve the diving characteristics of the Towfish. The large K-Vane® Depressor is also available. The K-Vane® attaches separately and is used for deeper or faster towing. See separate data sheet for additional details.

—Built-In Relocation Pinger

An optional Pinger Beacon Attachment (Model 212-00100) may be attached to the Towfish. The Pinger activates automatically when the sonar is lowered in the water and runs on its own internal battery. It can be used to locate the Towfish on the sea floor in case the tow cable should break. The Pinger has a detection range of 2000 to 4000 meters and a 30 day operating life. Klein Associates has a Pinger Beacon Underwater Locator Receiver available for use in emergency. A Pinger Test Set is also available for checking the Pinger on the deck of the ship.

MODEL 422S-101HF TOWFISH SPECIFICATIONS

--Output Frequencies:	100 kHz	500 kHz
—Pulse Length:	0.1 M Sec	0.02 M Sec
--Horizontal Beam:	1 Degree	0.2 Degrees
--Vertical Beam:	40 degrees tilted down 10 degrees below horizontal	40 degrees tilted down 10 degrees below horizontal
--Max. Range Per Ch:	300 to 500 Meters	50 to 150 Meters
--Acoustic Output:	228 DB Reference one micropascal at one meter	216 DB Reference one micropascal at one meter
—Weight in Air:	59 lbs (26.5 KG)	
--Length:	56 Inches (142.25 CM)	
—Diameter	3.50 Inches (8.90 CM)	
—Construction Material:	316 Stainless Steel	
—Safety Line:	Yes	
--Depth Rating:	1,000 Meters	



...THE NEXT GENERATION  
FROM THE WORLD LEADER  
IN SIDE SCAN SONAR AND  
SUB-BOTTOM PROFILERS

# KLEIN DIGITAL SONAR - SYSTEM 590

.....THE NEXT GENERATION

The Klein 590 series of HYDROSCAN® Side Scan Sonar and Sub-Bottom Profiling Systems is the most significant advance since we introduced the first seabed survey systems two decades ago. The basic 590 System consists of the Model 595 Graphic Recorder, the Model 422S-101HF Simultaneous Dual Frequency 100 kHz/500 kHz Side Scan Sonar Towfish and a 100 Meter high-strength, lightweight multi-channel tow cable. Each of these components is new, and they all represent the state-of-the-art in the sonar field. The 595 Graphic Recorder is controlled by a powerful microprocessor and includes a wide variety of capabilities including image correction, record expansion, sophisticated annotation and menu-driven operation. A versatile display format allows the operator to print up to four channels with a wide variety of options as listed in the Menu Options below. The 595 also features a totally new, fixed head, high resolution, high speed, dry thermal printer in which each dot is individually addressed to produce 16 distinct gray shades. The system is designed to be easily expandable. For example, current Klein customers can obtain the 595 only and use it with their present towfish and cable. New customers can start out with a single frequency sonar towfish instead of the dual frequency unit, and later, as the budget permits, expand the system with the dual frequency unit, the sub-bottom profiler or other options.

Also included with each system is an A.C. Power Cord, a D.C. Power Cord, a Remote Event Mark Cable, a Tape Interface Cable Set, three rolls of Recording Paper and an Instruction Manual. The system is complete, and requires only a power source to make the finest sonographs of the sea bed.

A wide variety of options and accessories are available for the 590 system including Sub-Bottom Profilers, alternative Side Scan Sonar Towfish, Microprofilers™, Multiplexers, Armored Cables, many Towing Accessories, the full-ocean depth Klein SMARTFISH®, spares kits and tape recorders. Systems are available in modular form for mounting on manned, tethered and autonomous underwater vehicles.

## MENU OPTIONS:

DEFAULT VALUES ARE UNDERLINED

RANGE SCALES: 12.5, 25, 37.5, 50, 75, 100, 150, 200, 250, 300, 400, 500, 600, 750 METERS

SCALE LINES: OFF 5 10 15 20 25 50 METERS

CHANNELS: 1 2 3 4 NOTE-CHANNEL ASSIGNMENT IS:

- 1 1 2 1: Port 100 kHz Side Scan
- 3 1 4 2: Starboard 100 kHz Side Scan
- 1 2 1 5 3: Port 500 kHz Side Scan
- 3 4 1 5 4: Starboard 500 kHz Side Scan
- 5: Sub-Bottom Profiler

MAPPING MODE (Image Correction): OFF ON

SOURCE: TAPE MONITOR FISH TAPE

ALTITUDE: AUTO 0.0 - 75.0 METERS, MAN 0.0 - 75.0 METERS

ALTITUDE ALARM: OFF ON 2 - 30 METERS

SPEED: MANUAL 1.0 - 20.0 KNOTS

EXTERNAL 1.0 - 20.0 KNOTS

AUTO MARK: OFF ON 0:10 - 10:00 IN 10 SEC. INCREMENTS

EVENT COUNT: OFF UP DOWN

EVENT NUMBER: 0 - 9999

SIDESCAN EXPAND: OFF ON

SIDESCAN DELAY: 0 - 600 METERS IN 5 METER INCREMENTS

SIDESCAN DISPLAY: 10 - 200 METERS IN 5 METER INCREMENTS

PROFILER EXPAND: OFF ON

PROFILER DELAY: 0 - 600 METERS IN 1 METER INCREMENTS

PROFILER DISPLAY: 10 - 200 METERS IN 5 METER INCREMENTS

NAVIGATION SOURCE: PARROT, LORAN-C, GPS, MINI RANGER, TRISPONDER

FAS1 FEED (Rapid Paper Advance)

TIME: HH:MM:SS IN 24 HOUR FORMAT

DATE: DD:MM:YY

## SPECIFICATIONS:

CASE SIZE: 44.8 CM (17.6 IN) WIDE  
55.9 CM (22.0 IN) HIGH  
29.2 CM (11.5 IN) DEEP

FRONT PANEL SIZE: 48.3 CM (19.0 IN) WIDE  
57.8 CM (22.8 IN) HIGH

WEIGHT: 22.7 KG (50 LBS)

MOUNTING: STAND ALONE OR STANDARD 19 INCH  
RACK MOUNT, OPTIONAL RACK MOUNT CASE AVAILABLE  
MOUNTING ORIENTATION: ANY

POWER INPUT, SWITCHABLE A.C OR D.C.:  
A.C. 105-125 VOLTS OR 210-250 VOLTS,  
SWITCHABLE, 47-420 HZ,

SINGLE PHASE, 100 WATTS AVERAGE  
D.C. 23-30 VOLTS (INPUT PROTECTED FROM  
REVERSE VOLTAGE OR OVERVOLTAGE),  
100 WATTS AVERAGE

RECORDING PAPER: DIRECT THERMAL, DRY,  
ODORLESS, ARCHIVAL, BLACK AND WHITE  
WIDTH: 43.2 CM (17.0 IN)

LENGTH OF ROLL: 46 METERS (150 FEET)  
DOT DENSITY: 8 DOTS/MM (203 DOTS/IN)

OPERATING TEMPERATURE: 0° C TO +50° C

STORAGE TEMPERATURE: -40° C TO +80° C

GRAY SCALE: 16 SHADES, DIGITALLY CONTROLLED  
TOWFISH (SIDE SCAN): 100 KHZ 500 KHZ

HORIZONTAL BEAMWIDTH	1°	0.2°
VERTICAL BEAMWIDTH	40°	40°
PULSE LENGTH, MILLISEC	0.1	0.02
ACOUSTIC OUTPUT, DB. PEAK	228	216

TOWFISH LENGTH: 145 CM (57 IN)  
TOWFISH WEIGHT IN AIR: 27 KG (60 LBS)  
TOWFISH WEIGHT IN WATER: 23 KG (50 LBS)

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

## SYSTEM FEATURES:

**NEW DRY PAPER GRAPHIC RECORDER:** The new 595 Graphic Recorder uses the latest dry thermal paper. This plastic-based paper is tear resistant, scratchproof, odorless, archival and dimensionally stable. The 595 also features a built-in take-up reel and a paper cutter. If the Recorder runs out of paper, an alarm sounds and stops the printer. A stripe toward the end of the paper roll also warns of low paper. Built-in power supplies allow the system to be operated on the A.C. mains or on a D.C. power source such as batteries.

**USER FRIENDLY:** The 590 System is extremely friendly to the operator. Sonar tuning is automatic through the use of the unique Klein Automatic Digital Hands Off-Tuning<sup>®</sup>, the most advanced side scan sonar tuning available (manual tuning is available as an option). System control is superbly simple. All operating parameters are easily set up via a front-panel display menu and simple front-panel pushbuttons. The menu has default selections, so that the System is fully up and running the first time it is turned on. A built-in, long-life lithium battery maintains the real-time internal quartz clock as well as all of the most recent menu selections if the System is turned off or if the power fails. The operator can easily reset to the default settings if desired. The menu has automatic lockouts to help prevent impossible settings.

**FULLY CORRECTED OR UNCORRECTED RECORDS:** The System automatically produces side scan sonar records which are fully image corrected for slant range and speed distortions. This enables the operator to assemble K-MAPS<sup>®</sup> true-scale sonar mosaics. In this mode, the sonar data has the water column removed and the selected range setting sets the exact width of the sea bed swath to be displayed. The ping rate is maintained at an optimum rate to ensure as many pings on the target as possible (to maintain the excellent target detection and delineation characteristic of Klein systems). The image produced is also aspect ratio corrected, with the vessel's towing speed being either entered manually through the menu or externally from an RS232 interface to the navigation instruments on board the vessel. Altitude information is also entered either manually or it is extracted from the sonar signal with a tracking Kalman filter. Alternatively the System may be set to make uncorrected records for applications where the presence of the water column display is useful such as mid-water object search, fish location and gas seep detection.

**DELAY AND EXPANSION:** The System can delay and expand any portion of the sonar record over the full width of a recording channel. Segments as small as ten meters can be displayed. This allows the Recorder to act as an electronic "zoom lens" to expand an area of interest. For example, an interesting target at 300 meters range can be expanded so that 10 meters of the sea bed fills an entire 8 inch wide displayed swath. Within that 8 inch width, the target is resolved into almost 2000 pixels. In this manner, taped data may be played back and closely examined at leisure. Delay and expand is provided independently for the sidescan and for the sub-bottom channels.

**SOPHISTICATED ANNOTATION:** Events may be annotated on the records in a variety of ways. Automatic event marks may be placed at intervals ranging between 10 seconds and 10 minutes in 10 second increments. Manual events are placed on record with either a button on the front panel, or with a remote event mark cable. Each event mark may be accompanied by a variety of annotation. In its simplest form the event mark is a very thin horizontal line. This line may have an event number associated with it. The event number is automatically incremented (or decremented). The starting event number of a survey takes up where the instrument was last turned off (for those surveys which may take many days), or it may be adjusted through the menu. Along with the event number may be included the time or date, the scale line interval, and up to five lines of navigation or other external information.

**SIMULTANEOUS DUAL FREQUENCY SIDE SCAN SONAR:** The System has a built-in capability to operate with the unique Klein Simultaneous Dual Frequency (100 kHz/500 kHz) Side Scan Sonar. The two frequencies truly operate simultaneously, not alternately. This allows for extraordinary versatility in detection, classification and signal analysis. In keeping with Klein's philosophy of commitment to our customers, the new System is also compatible with all existing Klein Side Scan Sonar Towfish, Sub-Bottom Profilers and Microprofilers<sup>™</sup>.

**DIGITAL OR ANALOG INTERFACE:** The System has both digital and analog signal outputs so that it may be interfaced to digital or analog tape recorders as well as computers and image processing systems. The System has auto-ranging so that it will automatically adjust to the range setting of the taped data. Functions such as scale correction, delay and expansion can be done in real time or can be performed in post-processing from taped data. Both the altitude and the towing speed settings are recorded onto tape to allow the maximum flexibility in post-processing of recorded data. Navigation instruments talk to the System through an RS232 interface with menu-selectable protocols. Simply scroll to the Nav Source option in the menu and select the protocol from a number of possibilities including parroting, GPS, Loran-C and more. The System takes care of stripping the incoming data of superfluous information, and leaves the operator with latitude and longitude, or lane numbers as appropriate.

**RUGGED AND SERVICEABLE:** In keeping with the Klein tradition, the new 595 Graphic Recorder is extremely rugged, reliable and serviceable. Only the finest available components and construction techniques are used throughout. Most plug-in electronics are easily accessible from the front panel. The System is designed to have a long mean time to failure. In case of problems, the Recorder has internal diagnostics to aid in troubleshooting. For example, in case of a board failure the menu will be blanked out and the message "Printer Control Card not responding" will appear.

**WARRANTY:** Klein Associates equipment is backed by a one year Limited Warranty. A copy of our standard Warranty is available on request.

## RECORD INTERPRETATION

Klein Associates has available a manual on Side Scan Sonar Record Interpretation. Klein also offers formal operator training courses. Contact us for details.

**KLEIN TECH NOTES:** Klein HYDROSCAN® clients are put on our mailing list to receive KLEIN TECH NOTES. In this newsletter we advise our customers regarding system updating, special problems which may be encountered, operational tips and other matters of interest.

**NITELINE:** A Nighttime Inquiry Telephone Emergency Line is in effect at Klein Associates. Worldwide clients may reach key Klein technical and sales personnel on nights, weekends and holidays by simply dialing the company's telephone number (603) 893-6131. Trained operators will direct your call to appropriate personnel. The emergency service starts at the close of our business day on weekdays (typically 4:30 P.M.) and will remain in effect until the opening of our business day the following morning (typically 8:00 A.M.) The service is also in effect every weekend (Saturday and Sunday), holidays and other times our business is closed.



**TOWING ACCESSORIES:** Klein offers a complete line of Towing Accessories including cable depressors, towing winches, slip rings, termination kits, towing shock absorbers, snatch blocks, deck cables and strain members. For more details, please ask for our Towing Accessories brochure.

**ABOUT THE COMPANY:** Since its founding in 1968, Klein Associates, Inc. has been a pioneer in the development of side scan sonar, sub-bottom profilers and related instruments and accessories for undersea search and survey. We design, manufacture and support equipment which has a worldwide reputation as the standard of excellence in the industry.

The Company has an experienced staff of technical personnel who are familiar with the demanding requirements of the ocean environment. We are small enough to give you personal attention, yet big enough to give you excellent service. We maintain an extensive inventory of spare parts ready for rapid air shipment to your location. We have sales and service representatives in many key locations around the world. Several of these representatives have systems and spare parts in stock for immediate delivery.

Our worldwide clients include Engineering Survey Companies, Geology Survey Departments, Hydrographic Surveyors, Pipeline Companies, Oil Companies, Archaeologists, Marine Salvors, Port Authorities, Treasure Hunters, Universities, Research Institutions, Submersible Operators, Environmental Consultants, the United States Navy, and many worldwide Navies.

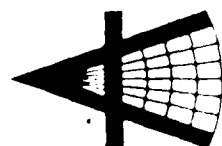
Klein equipment has an extraordinary record of success. Our sonar systems have been used to help find the *Titanic*, the *Atocha*, the *Lusitania*, the *DeBraak*, the *Hamilion* and *Scourge*, the *Breadalbane*, the *Edinburgh*, the *Republic*, the wreckage of the *Space Shuttle Challenger* and countless others.

We have a 30,000 square foot facility which includes two large acoustic test tanks and a pressure vessel for simulating deep ocean pressure.

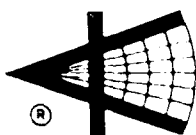
In addition to our line of standard products, we invite customer inquiries for special systems or service. Please feel free to call on us for assistance in your application.

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MAKING THE OCEAN TRANSPARENT™



**KLEIN ASSOCIATES, INC.**  
**UNDERSEA SEARCH AND SURVEY**  
KLEIN DRIVE SALEM NEW HAMPSHIRE 03079 U.S.A.  
PHONE (603) 893-6131 TELEX 947439 CABLE SONAR



# KLEIN ASSOCIATES, INC. UNDERSEA SEARCH AND SURVEY

Klein Drive • Salem, New Hampshire 03079 • U.S.A. (603)893-6131 • Cable: SONAR • Telex: 947439

PRICE LIST FOR  
MODEL 590 SYSTEM COMPONENTS  
EFFECTIVE 17 JUNE 1987

<u>Item</u>	<u>F.O.B. Salem, NH U.S.Dollars</u>
Model 595 Recorder - When Configured To Accept:	
- 100 kHz/500 kHz Dual Frequency Side Scan and 3.5 kHz Profiler Data	\$41,325.00
- 100 kHz/500 kHz Dual Frequency Side Scan	\$39,203.00
- 100 kHz or 500 kHz and 3.5 kHz Dual Frequency	\$35,490.00
- 100 kHz or 500 kHz Single Frequency	\$33,368.00
Model 422S-101HF Dual Frequency Towfish	\$22,500.00
100 Meter Multi-Channel Lightweight Tow Cable Longer lengths available at \$15.93 per additional meter.	2,993.00
100 Meter Multi-Channel Armored Tow Cable Longer lengths available at \$13.98 per additional meter.	2,698.00*
*Armored Cable Cut and Reel Charge, per length	175.00

PRICES ARE SUBJECT TO CHANGE WITHOUT NOTICE

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